Options Paper
Science, Impacts and Adaptation

Prepared by:
Canadian Climate Program Board

As a contribution to:
Canada's National Implementation Strategy on Climate Change

November 25, 1999

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Executive Summary

The concentration of greenhouse gases, particularly carbon dioxide, in the atmosphere has increased substantially and is expected to continue as a result of human activities. These increased greenhouse gas concentrations are and will continue to affect the climate. The issue of climate change will be with us for generations and will affect all aspects of our society and all parts of our country. We still cannot say exactly what the nature of the impacts will be, when they will become significant and where they will be felt most acutely. Nevertheless, the threat is real. We must act now to reduce these uncertainties so that we can inform and protect our citizens, as well as the ecosystems and economies on which they depend. We need to reduce these uncertainties if we are to make the right choices about how to respond to the threat of climate change.

The key to addressing climate change is to understand what is happening to our climate, how it operates and how it can be modelled. This will enable us to look into the future, to anticipate changes to the climate and the impacts that will follow. With the knowledge that comes from this understanding we will be better able to guide Canadians and the choices they will have to make regarding the rate and magnitude of future emissions reductions and the strategies for adapting to the inevitable impacts.

This Options Paper, prepared by the Canadian Climate Program Board (CCPB) and its two Advisory Committees, examines issues related to climate system science, impacts and adaptation as a contribution to the National Implementation Strategy on Climate Change. The recommendations proposed in the Options Paper will position Canada to:

- significantly enhance our scientific capacity across the country to understand and predict the climate and to foresee the impacts on Canadians and our socio-economic and environmental systems;
- prepare Canadians so that their exposure to risks from climate change can be reduced by the development of adaptive options that minimize economic and social costs, sustain their well-being and protect vulnerable ecosystems;
- provide information to Canadians and decision-makers so that they may make wise choices regarding future greenhouse gas emission reductions and implement suitable adaptation strategies;
- allow Canadians and their governments to participate knowledgeably, and from a position of scientific credibility, in domestic and international discussions related to the climate change actions, for example on the use of sinks;
- make a suitable contribution, as a developed country and in our own self-interest, to our knowledge of the climate, its future evolution and possible impacts; and
- meet our Framework Convention on Climate Change (FCCC) and Kyoto commitments on systematic observations, climate research and impact studies.

The CCPB has proposed the following integrated package of measures. They are all needed now.

With respect to **climate system science** the recommendations address the following three key areas:

- Climate observations
- Enhance understanding and reduce uncertainties
- Predicting future climate

Climate observations: *It is recommended that Canada strengthen its observational networks in order to better monitor, detect and attribute changes in the climate system.* Observations are the basis for understanding and predicting the climate, yet Canadian networks, particularly in the Arctic and our surrounding oceans, are inadequate. Internationally, Canada has made commitments under the FCCC and the Kyoto Protocol to undertake systematic observations of the climate system. The climate observation component should be managed by a new national mechanism such as a *Board for Systematic Observations* in order to ensure maximum benefit. There are two primary elements recommended:

- *augment systematic observation networks for all five components of the climate system*: atmospheric, oceanic, terrestrial, hydrologic and cryospheric.

- *undertake a research component directed at the development, testing and implementation of innovative approaches to monitoring.* The emphasis should be on exploitation of remote sensing aspects to enhance coverage of the systematic network and to reduce long-term costs.

Enhance understanding and reduce uncertainties: *It is recommended that research be undertaken to advance our understanding of the climate system with an emphasis on information that is required to provide a firm scientific basis for Canada's position in international negotiations, particularly regarding greenhouse gas sources and sinks.* There are two primary elements recommended:

- *implement a program to study greenhouse gas sources and sinks processes*, especially those in our forests, agricultural soils, wetlands, and oceans.

- *undertake a series of field and laboratory studies to reduce the scientific uncertainties* in the operation of key climate processes such as in the Arctic (ocean circulation and sea-ice behavior) and in the forcing of the atmosphere by clouds and aerosols.

Predicting future climate: *It is recommended that additional efforts be undertaken to improve projections of future climate, particularly on a regional scale.* The work is urgently needed for impacts and adaptation studies and to inform future international negotiations. There are four key elements recommended:

- *strengthen our ocean modeling capacity*. There is a need to build a stronger capacity for ocean model development in Canada. Gaps in regional and basin scale ocean models need to be addressed, and techniques developed for the assimilation of this data into models.

- *strengthen the Climate Research Network.* This government/university initiative should be expanded into areas where the largest scientific uncertainties exist, such as the carbon cycle, clouds and radiation and extreme climate events. This would also accelerate building of Canadian scientific capacity, particularly in universities.

- *enhance the national climate modeling capacity.* This would enhance Canada's climate modeling expertise in the Canadian Centre for Climate modelling and analysis (CCCma), strengthening our skill at making predictions at regional scales, and ensuring supercomputer capacity is available to run these increasingly complex models.

- *establish a facility for the provision of climate scenarios.* There is a need to establish an ability to provide packaged climate model outputs (scenarios) to researchers involved in impacts and adaptation studies. The capacity would be a collaborative enterprise between the universities and the federal government.

The recommendations for the climate system science have been designed such that they can operate in a synergistic fashion, and feed needed information to the impacts and adaptation researchers as well as the policy community. For example climate models, and study of climate processes, depend on availability of climate observations. In turn, results from climate process studies can help better delineate at what spacing and frequency climate observations should be made. Climate scenarios are only as credible for regional impact studies as the regional climate models that they are based upon.

In concert with the above issues, the CCPB believes that recommendations in **impacts and adaptation** issues should be addressed within four complementary components:

- Research program
- Program delivery
- Capacity building
- Adaptation governance

Research program: Impacts and adaptation research are relatively new areas and there are a number of priority issues. *It is recommended that an impacts and adaptation research program be implemented to address these issues.*

Program delivery. Impacts and adaptation research efforts in Canada are not well coordinated. To provide coordination of research activity, climate impact assessments, and a mechanism for stakeholder involvement, *a Canadian Climate Impacts and Adaptation Research Network (C-CIARN) should be established with regional and sectoral composition.*

Capacity building. To ensure that the Canadian research capacity in governments, universities and industry can deal with the range of issues that must be addressed, *a significant investment in analytical capacity and a targeted research program should be made now, to enhance scientific capacity in impacts and adaptation.*

Adaptation governance. *An appropriate governance structure should be established for dealing with impacts and adaptation research results.* Implementation of adaptation measures will involve governments at all levels as well as the private sector and individuals. At the national level there will be a need to address *inter alia* implementation costs and barriers and conflict resolution. A formal process needs to be set up, similar to that for mitigation, to guide the analysis of adaptation options.

The CCPB recommends that Canadian climate change scientists be engaged to participate in a major climate change **communications** *initiative.* Independent studies confirm that there is no community more qualified or respected to communicate the facts and consequences of climate change than the climate system science, impacts and adaptation research community. In addition, the governments have a responsibility to ensure that all sectors of the policy-making community have access to sound science and to scientists who are actively researching the answers. A communications program encompassing these concerns would be characterized by the following thrusts:

- Public education and outreach
- Dialogue with decision-makers

Public education and outreach. *It is recommended that an initiative be created to improve the Canadian public's understanding of climate change, the need to reduce greenhouse gas emissions and take measures to adapt to climate change.*

Dialogue with decision-makers. The objective of this initiative would be *to initiate a dialogue with industry and all levels of government to ensure that state-of-the-art climate system science, impacts and adaptation information is available for decision-making.* Consideration should be given to supporting the Canadian Climate Program Board to implement this initiative.

Foreword

1. Climate change is an issue of global dimensions and has to be tackled on an international basis. With 0.5% of the World's population, Canada contributes 2% to the World's annual emissions of greenhouse gases. However, we could experience significant impacts that could disturb our social and economic well-being as well as the ecosystems on which we depend. The exact details of future climate change are difficult to predict. We do not know precisely when the impacts will become significant or where they will be felt most acutely. Reducing these uncertainties will be essential in addressing climate change.

2. Emissions of greenhouse gases, such as carbon dioxide, methane, nitrous oxide and CFCs, have been increasing since the industrial revolution. As a consequence, concentrations of these gases in the atmosphere have reached levels higher than for many thousands of years. As long ago as 1896, the Swedish Nobel Prize winner Arrhenius argued that this would lead to a warming of the lower atmosphere and hence to changes in the climate. This concern was raised again by the British scientist Callendar in 1938 and was the subject of a White House study by the late Roger Revelle in the mid-1960s. International political concern was increased significantly in 1985 by the report of a group of scientists gathered at a conference in Villach, Austria. There followed a series of international meetings that rapidly attracted the attention of governments. One of these meetings was held in Toronto in 1988. Although intended to draw attention to the many changes in the composition of the atmosphere that were taking place, the Conference focussed mainly on the issue of climate change. It was the first meeting to issue a call to governments to reduce their emission of greenhouse gases (by 20% of 1988 levels by 2005 as an initial goal).

3. In order to provide authoritative assessments of our knowledge of this issue, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in 1988. Its first report was published in 1990. It documented scientific evidence linking greenhouse gas emissions from human activities to the risk of global climate change. The report was reviewed at the Second World Climate Conference in the same year. This land-mark meeting led to the establishment by the United Nations General Assembly of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (FCCC). The Convention was signed by 154 countries at the Earth Summit in Rio de Janeiro in 1992 and entered into force in 1994 - it has now been ratified by some 175 states.

4. The second IPCC Assessment was completed at the end of 1995. Its conclusions played a major role in galvanizing the views of governments at the third Conference of the Parties under the Framework Convention (CoP III) in December 1997 in Kyoto. At Kyoto, countries took the first step towards quantified emission reductions. For Canada, the Kyoto Protocol contains a commitment to reduce its emissions of greenhouse gases by 6% from 1990 levels during the period 2008 - 2012. Since Canada's emissions have been rising steadily and are now projected to be some 20 to 25% higher than in 1990, this reduction represents a considerable undertaking.

5. While the Framework Convention and the Kyoto Protocol both focus on emission reductions as an essential response to the threat of climate change, they do recognize the need for other actions. In the medium-term, global emissions will continue to increase and, since these gases remain in the atmosphere for decades to centuries, further increases in atmospheric concentrations and hence changes to the climate system are inevitable. Thus one of the actions that has been included in the FCCC and the Kyoto Protocol is adaptation to the impacts of the climate change. It is also recognized that any response action will require a solid scientific foundation in monitoring the state of the climate and in improving our understanding of and ability to model and predict changes in the climate system.

Chapter 1: Introduction

1. The threat of the impact of climate change on the economy, society and ecosystems has captured the attention of governments and galvanized their resolve to tackle the issue. Addressing climate change in Canada has to be seen as a long-term challenge but one that we have to start to attack now. There are two main response actions:
    - reducing emissions to slow the rate of increase in atmospheric concentrations of greenhouse gases and hence the rate and magnitude at which the climate will change, and thus the potential impacts; and
    - adapting to the impacts [1] of climate change so as to protect our citizens, their infrastructure and economies as well as our ecosystems. Science[2] is essential to provide the solid basis needed for the development of both response actions and to engage Canadians.

2. Our knowledge of climate system science[3] has advanced considerably over the past decade or so. Canadian scientists have made significant contributions and this has enhanced our voice in the international arena and prepared us to begin to deal with the threat. However, our understanding of the complex behavior of the climate system and its impacts is incomplete. Uncertainties remain regarding the causes, impacts, magnitude and timing of climate change. Further investments are needed to reduce these uncertainties so that our ability to predict what might happen in the future is improved. This is essential if we are to reduce the costs of responding to climate change. As a large, northern, developed country we have a self-interest as well as an international responsibility to understand better the nature of the threat of climate change.

3. A national process was created shortly after CoP III to determine how Canada could meet the commitments contained in the Kyoto Protocol. This process will lead to the development of a National Implementation Strategy (NIS). The cornerstones of the process are Issue Tables that have been commissioned to produce Options Papers that bring together relevant background studies. The Science, Impacts and Adaptation Options Paper is the responsibility of the Canadian Climate Program Board (CCPB) and its two Advisory Committees.

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[1] Impacts may be chemical, biological, geophysical, social, economic or health related. They can be either negative or positive.

[2] Science for the purposes of this document refers broadly to many disciplines, including the natural, social, economic and life sciences and the humanities, which are engaged in the climate change investigations.

[3] The climate system is defined as the atmosphere, the ocean and the land surface as well as the fluxes of heat, momentum, moisture, greenhouse gases and aerosols between them. It includes all the processes on the land that affect these fluxes, including hydrologic, cryospheric processes including ice on the oceans, lakes or land etc. It also includes the effects of vegetation, evapotranspiration, carbon storage and release in soils and wetlands, etc. On longer time scales it includes plastic deformation of the earth's surface by ice sheets, glaciers. etc.

4. The objectives of this Options Paper are to lay out recommendations for a climate monitoring, research, impacts studies and adaptation program. The document aims to reflect the concerns of the Canadian research and policy communities. It presents information on the current state of the scientific enterprise in Canada and proposes measures that, if adopted, will provide Canada with a solid scientific basis for addressing the climate change issue.

5. In developing this Options Paper we first explain, in Chapter 2, why the potential impacts of climate change in Canada have stimulated concern and the need for action. Chapter 3 elaborates on the links between this Options Paper and others that have been produced and that focus predominantly on measures to reduce emissions or enhance sinks. More importantly, it illustrates that the Kyoto Protocol is only a first step and that further emission reductions will be necessary. In Chapter 4, we discuss the types of impacts expected and adaptation as the other principal response action, and lay out arguments for building a program in Canada to study impacts and to develop appropriate adaptation options and strategies.

6. Chapter 5 details the elements of a program to provide the climate system science necessary to reduce our present scientific uncertainties and to inform mitigation and adaptation initiatives and decision-making processes. It includes elements for improving our capacity for systematic climate observations, understanding and modeling the climate system, and predicting the impact of climate change in Canada. Chapter 6 provides recommendations on communication of science and some of the key messages.

7. Specific recommendations on climate system science, impacts and adaptation are presented in Chapter 7. These recommendations, based on the material contained in chapters 3 through 6, reflect the CCPB's view of the level of resources required to realize a coherent and robust program. Such a program would provide Canadians with an understanding of the changes to the climate of today and tomorrow, the anticipated impacts of these changes and the information to allow them and their governments to make well informed choices and take prudent action.

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Chapter 2: Impacts - Reason for Concern

1. We know that the climate is changing and that Canada is vulnerable to that change. We also know that, even with the reductions in greenhouse gas emissions agreed to at Kyoto, atmospheric concentrations will continue to increase. These increasing concentrations will mean that there will continue to be changes in climate to which Canada and Canadians will have to adapt.

How is Climate Changing

2. In 1995, the IPCC noted that, globally, mean surface air temperatures have increased between 0.3 and 0.6 degrees C since the late 19th century. This value was updated recently (1999) by the World Meteorological Organization to 0.7 degrees C. Canada has warmed approximately 1degree C during the past century, with regional variations ranging up to about 1.5 degrees C over the western Northwest Territories. The IPCC estimates that the mean annual global surface temperature will increase between 1 and 3.5 degrees C from "business as usual" due to greenhouse gas and aerosol emissions by the year 2100. To put this change in perspective, scientific reconstruction of the past climates reveal that during the peak of the last major ice age, some 15,000 years ago, the mean annual temperature was only about 5 to 8 degrees C different than today.

3. But climate change is more than just a change in mean temperature. There could also be changes in the frequency, severity and duration of extreme events and a more vigorous hydrological cycle. Canada is likely to experience an increase in floods due to more intense rainfall and snowfall in some regions. Conversely, some regions could experience an increase in droughts as precipitation decreases and temperatures rise. Recent extreme events in Canada, such as the 1998 ice storm in Eastern Canada, and the 1997 Red River flood, demonstrate that such events can have major costs for Canadians. While these types of "extreme" events cannot be directly attributed to climate change, they are indicative of what the climate models predict could occur more frequently as a result of climate change.

The 1998 Ice Storm

The unusual ice storm that hit Ontario and Quebec in January 1998 was caused by the combination of unusually mild temperatures, the transport of excessive moisture into the region from the tropics, and a high pressure system over the Atlantic that maintained these conditions for an extended period of time. Recent estimates suggest that the total cost to the Canadian economy due to this storm alone could exceed $4 billion. There were also extensive additional ecological and social costs. The strong El Niño conditions were a factor. Model projections of future climates suggest changes in the pattern of global sea surface temperatures similar to that occurring during El Niño events.

Impacts of Climate Change

4. There is convincing evidence that our climate is already changing, and that these changes are unprecedented in at least the past 1400 years. High temperatures have persisted throughout the 1990s, and a number of unusual biophysical impacts are already evident within and adjacent to Canada.
    - In the Arctic: ice extent has declined at a rate of 2.9% per decade since 1978, with record minimum ice coverage occurring frequently in the 1990s. Faunal distributions also appear to be changing.

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- Recent decadal measurements show an increase in glacier mass loss at a rate commensurate with that expected to be produced from human-induced radiative forcing.
- There has been a significant reduction in spring snow cover and late-winter to early-spring snow depths over much of Canada and especially western Canada since 1950.
- Permafrost in much of western Canada and in Alaska is warming to the extent that the southern permafrost region of Alberta may eventually disappear.
- One of the largest outbreaks of insect-caused (spruce bark beetle) tree mortality in the history of North America has decimated over 3 million acres of Alaskan white spruce forests - spruce bark beetle populations are historically kept in check by cool summers and cold winters.
- Parts of the boreal forest, and parkland aspen are showing signs of climatic stress.
- Prairie grasslands are moving northward.
- Water temperatures of inland waters are warming, with associated impacts on aquatic species.
- In parts of the Pacific Northwest, disease vectors such as deermice have proliferated because of the warmer and wetter weather.
- Damage from relative sea level rise and storm surges is a persistent problem on Canada's coasts: Fraser Delta, and Atlantic Canada.
- There has been a cooling of surface ocean temperatures off the coast of Labrador and less warming in Atlantic areas, as projected by climate models.

5. Canadians are being and will continue to be affected by the biological, physical and other responses to climate change. When the activities of humans are superimposed on a changing climate, the effects can be pronounced. The impacts can be both positive and negative. The negative impacts we wish to limit and we want to maximize the positive benefits. A few of the socio-economic and heath care impacts that we are seeing or that are projected to manifest themselves shortly are:
    - warmer winters, with important implications for road infrastructure costs, tourism and recreation, and other sectors;
    - human population health concerns related to direct and indirect effects of climate change (e.g., increased frequency of heat waves and possible northward migration of diseases); and
    - the effect of warmer temperatures and changes in precipitation patterns on the agriculture, fisheries and forestry sectors.

Mitigation to Reduce Impacts

6. The IPCC has estimated that industrialized nations are responsible for 84% of industrial CO_2 and two-thirds of combined CO_2 and methane emissions now present in the atmosphere. In the future, however, developing countries will account for a much larger share of the growth of greenhouse gas emissions. At Kyoto the industrialized countries of the world committed to taking an international lead in mitigation[4] of greenhouse gases. Emission increases, assuming business as usual in developing countries, are expected to be much greater. The reduction of greenhouse gases is a global problem, not just a Canadian problem.

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[4] Mitigation is the anthropogenic intervention to reduce the emissions or enhance the sinks of greenhouse gases.

7. Unless special efforts are made to bring them under control, greenhouse gas emissions will continue to rise as a result of normal population and economic growth. Their concentrations will only stabilize if there are significant world-wide reductions in emissions. The atmospheric concentration at which stabilization will occur will depend on how far and how rapidly emissions are reduced. Kyoto is but the first step.

Adaptation to Lessen the Impacts

8. As illustrated at the end of this chapter, there are two main responses for limiting impacts: mitigation and adaptation[5]. We can lessen the effects of climate impacts by either reducing the amount of climate change through mitigation, or by adaptation-taking action to directly address the impacts. These two responses are not alternatives - we must consider both reducing our emissions to reduce the risks of future climate change and also adapting to the changes that are inevitable.

9. Adaptation measures should be considered to be included in the range of options considered by Canada in responding to climate change, because:
    - adaptation will reduce the vulnerability of Canadians and their health, their environment and their economic sectors to climate change and contribute to sustainable development in Canada ; and
    - adaptation decisions can be costly if they are not implemented in time: decisions being made today will impact on Canadians' vulnerability and their ability to adapt in the future.

Supporting Mitigation and Adaptation Decision-Making

10. Scientific investigation of the climate system put climate change on the public policy agenda, and continues to play a key role in our response. A highly integrated research program in support of climate system science, impacts and adaptation is needed for Canada's response to climate change. There are key questions or issues to be addressed under such a program.
    - How large and rapid will climate change be? How much will temperature and precipitation change? Will there be more natural disasters? In which regions will climate change have major impacts?
    - What will be the magnitude and types of impacts on our ecosystems, economy and communities? What will be the vulnerabilities and sensitivities of our society and our ecosystems to those impacts?
    - We know that there will still be surprises as the climate changes - can research give us advanced notice of this and or ideas for rapid adaptation?
    - The FCCC and the Kyoto Protocol contain explicit and substantial commitments for Canada relating to climate system science (both monitoring and research) and to adaptation. In addition there are other commitments that will require scientific knowledge that is not currently available or is incomplete, such as the behaviour of greenhouse gas sinks. How can we best ensure that we meet our international commitments and support our position in international negotiations?

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[5] Adaptation refers to the possible adjustment in practices, processes or structures of systems to projected or actual changes of climate; adaptation can be spontaneous or planned and can be carried out in response to or in anticipation of changes in conditions. It is action undertaken to minimize the risk and disadvantages of climate change while maximizing opportunities.

Climate Change and BC Salmon - A Case for Concern

The Fraser River is home to several species of Pacific salmon and is Canada's biggest salmon producer- millions of fish return each year to spawn, supporting commercial, recreational and First Nations fisheries.

Temperatures in the headwaters of the Fraser River system often reach 21-22 degrees in the summer, coincident with the return of fish to the spawning grounds. These temperatures are approaching lethal values now for the spawning fish. Furthermore, the warm water causes impairment of migratory ability, exhausting energy reserves of migrating fish, and interfering with reproductive success.

If the temperature regime continues to move towards warmer water, migration and spawning will be further impaired, and if the summer temperatures increase a degree or two most of the spawning fish will die, causing a collapse of the salmon resource. Climate models grounded in the state-of-the-art climate system science will serve as the foundation for determining the sensitivities of this ecosystem to increasing temperature.

Adaptive measures may include allowing more fish to enter the river to allow for en route mortality due to temperature increases; however, this means many fishermen will forego their catch. If conditions worsen to the point of becoming lethal to many of the fish, historic runs will be lost forever and major investments in hatcheries and stock rehabilitation will be affected. Adaptation strategies might include building hatcheries elsewhere, changing flow regimes to decrease temperatures, moving fishing activities to other species, aquaculture, etc. In any case, more research is required in order to provide the foundation for risk analysis and to choose the right mix of adaptive options.

Managing the Risk of Climate Change

11. Decision-makers must respond to the risk posed by climate change in the face of uncertainty. This relates to:
    - scientific - technological, social and economic uncertainties associated with the projections of climate change;
    - biophysical and human systems - a less than thorough scientific understanding of the functioning of these systems has made it difficult in many cases to quantify the impacts of climate change; and
    - policy instruments - the effectiveness of employing certain mitigative or adaptive measures and their impacts on other environmental and socio-economic problems.

12. Uncertainty however, is not an excuse for inaction. Uncertainty is best address by managing the risks associated with decisions. Given the evidence provided by the scientific community, world leaders have deemed it prudent to begin to address the issue of climate change. Nationally, decision-makers are challenged to meet our Kyoto commitments by designing an integrated package of mitigative and adaptive measures. Issues of equality, timing of measures, monitoring impacts of decisions and re-evaluation of effectiveness of the package are important elements of this response. Ultimately, addressing climate change will involve making a series of resource choices: choices that will be affected by uncertainties. Decision-makers will have to evaluate the risks involved in making these choices. While an elaboration on risk management is

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not the primary focus of this Options Paper, it is worthy of note that science provides an informed basis for managing the risk of decision-making.

Scientist Role in Public Education and Outreach

13. Public commitment to the reduction in greenhouse gas emissions and to adaptation depends in part on Canadians understanding the scientific basis for concern about climate change, its consequences and its implications for sustainable development. The results of climate system science, monitoring, impacts studies and development of adaptation options need to be accurately and effectively communicated to Canadians. The climate system science, impacts and adaptation community have a responsibility to assume a dialogue with Canadians from all walks of life regarding their climate change concerns.

The Excellence of Canadian Climate System Scientists

Canada's global climate modelling team, based in Victoria, have developed one of the most advanced models of the climate system now available. Model results confirm that it can replicate the behaviour of the current climate very well. Projections for future climates, if humans continue to emit greenhouse gases and aerosols into the atmosphere without controls , suggest that Canada could, on average, become 5-6 degrees warmer by the mid-20th century. The Canadian model projections have been accepted by the IPCC for further distribution to researchers around the world for impact studies. A second modelling team at the University of Quebec at Montreal is now developing a complementary regional climate model that can use the global model outputs to generate more detailed descriptions of possible future climate change.

Canadian researchers have also gained high respect from the international scientific community in a number of other climate change related areas of investigation. These include the study of ocean dynamics and biogeochemistry, hydrological processes within terrestrial ecosystems, the role of the Canadian soils, boreal forest and wetlands in the global carbon cycle, and methodologies for studying the impacts of climate change.

International Responsibilities and Opportunities

14. The global nature of climate change has created the need for international scientific co-operation which has benefited the Canadian policy and scientific establishment. Canada is a major player in these science and policy frameworks and it is vital that we maintain and strengthen our national commitment to:
    - monitoring networks to support climate change detection and attribution studies;
    - improved understanding of the behaviour of greenhouse gas sources and sinks; and
    - improved information on regional-scale vulnerabilities and impacts in order to formulate adaptation responses.

15. There are several specific commitments with respect to the international science dimension.
    - The IPCC Third Assessment Report due in 2000/01 is being prepared now and will be the major scientific contribution to the future evolution of the FCCC.
    - Canadian scientists have committed to contribute to this Assessment and the science informing these Assessments needs to be supported.
    - Climate system science dealing with greenhouse gas sources and sinks is needed to support the Canadian position at international negotiations.

not the primary focus of this Options Paper, it is worthy of note that science provides an informed basis for managing the risk of decision-making.

Scientist Role in Public Education and Outreach

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- There are specific commitments in the FCCC and the Kyoto Protocol directed toward monitoring the climate and tracking climate change. At the fourth Conference of the Parties in Buenos Aires, in 1998, parties were encouraged to develop national plans for observing climate.
- It is vital for Canada to recognize its role in nurturing the scientific capacity in developing countries such that those nations can benefit from a domestic perspective on climate change mitigation and adaptation decisions.
- It is not only in our self interest to formulate, publish and update national and regional programs to document the impacts of climate change, and facilitate adequate adaptation to climate change, but the FCCC and the Kyoto Protocol, as well as our ongoing commitment to the IPCC assessments, require that we do it.

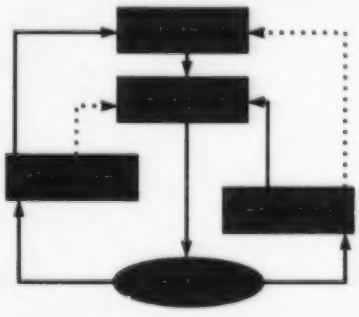
Summary

16. There is a general scientific consensus that climate change is already happening and that the risks of significant climate change are real. The observational record, output of climate models and the results of climate change impacts collectively indicate that there is reason for concern. Climate system science has provided the basis for international recognition of this issue. It will continue to underpin our mitigative and adaptive responses to climate change.

17. The formulation of mitigation and adaptation strategies is an evolving process. Evolution will take place as new targets and processes are negotiated, as our knowledge improves, as new technologies come on stream and as we clarify potential residual impacts. To be successful these areas we would be well served b having an adequate science base. To support mitigation and adaptation requires that we invest in targeted scientific research.

18. Although there is uncertainty about the implications on humanity of future climate change, we have inadequate knowledge on how we can best adapt to climate change and offset adverse present and future impacts, and also take advantage of future positive impacts. Adaptation is not a replacement for mitigation. We require both. Indeed, mitigation efforts are a precondition for the success of adaptation strategies, because adaptation is more likely to succeed if climate change is kept to a moderate pace and human pressures on the climate system are eventually stabilized.

Mitigation and Adaptation



Recommended Reading

The Canada Country Study: Climate Impacts and Adaptation, National Summary for Policy Makers, Canada,. Environment Canada, 1997.

IPCC, Climate Change 1995: Impacts, Adaptation and Mitigation of Climate Change (Working Group III), 1995.
Chapter 3 - Science for Kyoto Emissions Reductions (Mitigation)

Science Relevant to Policies on Greenhouse Gas Emissions Reductions

1. As noted in Chapter 2, the Kyoto Protocol requires that the scientific basis for Canada's measures to mitigate the risks of climate change must be credible. Judicious selection of measures to achieve the objectives of Kyoto will require a good understanding of the effectiveness of such measures within a changing environment. To do so, related gaps in the relevant scientific knowledge and information must be properly addressed within both the national and international context.

Climate Change Action Fund - Science, Impacts and Adaptation
The goal of the science, impacts and adaptation component of the Climate Change Action Fund (CCAF) is to address key gaps in science needed to help Canada meet its obligations under the Framework Convention on Climate Change and the Kyoto Protocol. The CCAF results are to support a national long-term plan for climate system science, impacts and adaptation. The federal and provincial governments, university researchers and the private sector would deliver this plan.

Over the past year, the CCAF has initiated several targeted scientific workshops and requests for proposals to catalyze Canadian science to support decision making in the following areas:
Climate Model Improvements
Global Climate Observing Systems
Greenhouse Gas Sources and Sinks
Arctic Climate System Research and Monitoring
Impacts and Adaptation

In addition to funding research planning and activity, CCAF funds will support Canadian scientists involved in the Intergovernmental Panel on Climate Change (IPCC), with the primary support directed to those involved as lead authors in chapters of the Third Assessment. Nearly thirty Canadian scientists, split about equally between university and government experts, receive CCAF support.

2. There are two key scientific concerns:
    - There are important scientific uncertainties with respect to how carbon is stored in our forest, soil and wetland ecosystems, how carbon accumulates and is retained within these sinks, and how measures adopted to sequester carbon may affect the emissions of other greenhouse gases. There are equally important uncertainties in the sources of greenhouse gases from agricultural and other managed ecosystems.

    - Changes in temperature and water resources under warmer climates may have important implications for the long-term effectiveness of some of the mitigation measures being considered as options for meeting the Kyoto commitment.

3. The following sections present an assessment of these needs, and provide recommendations for consideration within the National Implementation Strategy.

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The Climate System Science Relevant to Carbon Sequestration [6]

4. Canada is a vast country consisting of a broad range of complex and diverse ecosystems. These include Arctic tundra systems, coastal salt marshes, interior wetlands, prairie grasslands, boreal forests, temperate deciduous forests and coastal rain forests. The rate at which each of these ecosystems take up and release carbon dioxide and other greenhouse gases is critically dependent on a number of variables, including local temperature and hydrology, soil conditions, topography, natural disturbances and time of season. These conditions can vary dramatically from one metre to the next within an ecosystem, and from one ecosystem to the next. Some also change dramatically from one day to the next. Furthermore, as climate changes, some of these controlling variables may change well beyond their historical ranges, and thus expose Canadian ecosystems to conditions unprecedented in recorded human history.

5. As noted in the Greenhouse Gas Sinks Table, Forest Sector Table and Agriculture and Agri-Food Table Options Papers, the area of Canadian ecosystems affected by human activities, (and therefore to be assessed for contributions to sources and sinks of greenhouse gases under the Kyoto Protocol and subsequent agreements), can be estimated with reasonable accuracy provided that improved land use inventories and more careful monitoring systems for land use change are developed. However, the magnitude and sustainability of the carbon sink (that is, the net quantity of carbon dioxide removed from the atmosphere and stored as carbon) per hectare of land area involved is much more difficult to establish, particularly if climate conditions and other controlling environmental factors change significantly. Furthermore, changes in land use also have poorly understood implications for emissions or removal of other greenhouse gases, such as nitrous oxide and methane. Thus these uncertainties present important barriers to credible and verifiable reporting of sustainable carbon sinks and other greenhouse gas fluxes resulting from carbon sequestration measures. Several key issues are described in the following paragraphs.

6. *Monitoring and Reporting of Sinks*. Available inventories of carbon stored within terrestrial ecosystems for selected sites across Canada have, in general, been developed independently for other purposes. This leads to a number of problems in assessing current carbon inventories and their status. There is a need, therefore, to develop appropriate definitions , and measurement and reporting procedures (involving a combination of space, airborne and surface monitoring systems) to address these problems. Furthermore, the sequestration of carbon in a particular ecosystem like a forest or an agricultural field may have related implications for adjacent systems such as wetlands, peat bogs or coastal ocean systems. For example, Canada's peatlands, which contain about 10 times as much carbon per unit surface area as forest biomass and agricultural soils combined, are primarily found within the boreal forests. Hence any measures to sequester carbon in the latter through afforestation, should consider the consequence for the production of methane and nitrous oxide within peat bogs. Since the related processes involved are poorly understood, the related effects of sequestration measures will be difficult to assess.

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[6] In this paper, carbon sequestration refers to the removal of carbon dioxide from the atmosphere by growing trees and other vegetation and its long-term storage within a stable reservoir, such as soils, wood in trees, or peat in wetlands. The stored carbon is also often refereed to as a carbon sink. If the carbon is released again as carbon dioxide, it is a carbon source.

7. *Long Term Viability of Sinks.* A second major concern in estimating the effects of Kyoto-related carbon sequestration projects is that much of the understanding we do have about processes that control carbon changes in our ecosystems do not extend to how these processes may change as the environment changes. Yet, as noted in Chapter 2, Canada's climate is already changing, melting permafrost is altering our northern systems, and forest age and species are being transformed. Increased concentrations of carbon dioxide and nitrogen compounds in the atmosphere (both of which are plant nutrients) will also directly affect the carbon flux processes within ecosystems. There is very little information on how these environmental changes will alter carbon flux processes within the ecosystems, and hence the estimation of carbon sequestration under the Kyoto Protocol is made more difficult.

8. *Developing Credible Tools for Reporting Carbon Sequestration.* While measurements and research into carbon flux processes can help address the above deficiencies in understanding, complex ecosystem models are needed to accurately describe these processes and relationships in an integrated and dynamic manner. While a number of such models have been developed within Canada and have gained considerable international recognition as quality tools for studying carbon dynamics within the respective ecosystems, these have been designed for applications other than assessment of carbon sequestration potential due to human management. They also continue to inadequately simulate the behaviour of some of the carbon components within soils, particularly those related to respiration. These models need to be further developed, validated against observations, and tested within the international climate system science community.

9. *Ocean Sinks.* Sequestration of carbon into the oceans, either through direct dumping of carbon dioxide into the deep ocean or by removal through enhanced biological production induced by iron fertilization activities in nutrient deficient ocean surface waters, is being investigated by some countries as an alternative approach for reducing the growth in atmospheric carbon dioxide concentrations. There are still many technical and environmental questions related to the viability or acceptability of such measures. It is unlikely, therefore, that they will be considered within national mitigation strategies under the Kyoto protocol in the near future. However, Canada's negotiators do need to be cognizant of the potential, the state of the climate system science, and the benefits and/or hazards of such sinks, should they be tabled by other countries. The very large potential magnitude of such sinks and the potential for irreversible, long-term harm to the ecosystem of enhancement techniques such as iron fertilization may make such research of particular importance in the long-term.

Science Relevant to Other Mitigation Options

10. Changes in temperature and water resources under warmer climates may have important implications for the long-term effectiveness of some of the mitigation measures being considered as options for meeting the Kyoto commitment. Furthermore, such measures may have indirect effects on the environment that may partially offset (or perhaps enhance) the expected reductions in greenhouse emissions. There are several related mitigation measures, as discussed below.

11. *Hydro-electricity.* Hydro-electricity offers an important alternative to producing electricity through the combustion of fossil fuels. However, hydropower relies on water resources, which are in turn vulnerable to changes in climate. Hence all mitigative measures that view increased use of hydro-electricity as a means of reducing greenhouse gas emissions must do so with the understanding that future distribution of rainfall and evaporation may change substantially from that of the past. Most studies

suggest that water resources will decrease in southern Canada but could increase in parts of northern Canada. However, there is still low confidence in our ability to predict changes in water resources. Some hydroelectric complexes also result in the flooding of large amounts of vegetation within the water storage reservoir. Studies have concluded that such flooding can result in the release into the atmosphere of large volumes of methane. Since methane is much more potent per unit volume as a greenhouse gas than carbon dioxide, some of the gains from reducing the greenhouse gas emissions by displacement of fossil fuel burning power stations may be negated. However, as with wetlands, the processes which govern the generation and release of methane from hydroelectric reservoirs remain as yet poorly understood and require further investigation.

12. *Wind and Solar*. Wind and solar power options for displacing the use of fossil fuels as a source of electrical power are sensitive to climate change. Solar power is limited by the amount of sunshine reaching the earth's surface. This in turn is determined in part by the amount and type of cloud cover, which may change as climate changes. They are also sensitive to the concentrations of aerosols, such as the acid-rain causing sulphates, that are released as part of our industrial activities. Yet cloud response to changing climate and the role of sulphates remain two of the most perplexing problems in modeling climate change today, and hence are high priorities for climate change research. Both need to be resolved to address their effects on performance of future solar powered energy projects. For wind powered energy sources, changes in wind intensity is the primary concern. Such changes are determined in part by large-scale changes in atmospheric circulation systems which dominate broad scale wind patterns and behaviour. However, geographical features that contribute to local wind conditions, such as lake and sea breezes, can also be of critical importance to wind power potential. Future changes in these variables and their contributions to wind power have been inadequately investigated.

13. *Biomass Energy*. Tree plantations for use as biomass fuels, whether through direct combustion or conversion to liquid fuels, could be important options for replacing fossil fuels. The selection of species and hence growth potential and success of such plantations depend on local temperature and precipitation regimes, and how they will change as the global climate is altered. These factors remain as yet uncertain, particularly at the local scale.

14. *Other Renewable Energy Sources*. There are other proposals for options to reduce greenhouse gas emissions that are also sensitive to climate change. Use of lake bottom waters, for example, to help cool buildings in summer and heat them in winter through the use of heat pumps, is sensitive to changes in lake temperature as climates change. Likewise, wave and tidal energy proposals are sensitive to changes in sea level and in wave heights. These linkages need to be explored.

15. *Energy Efficiency*. Many energy efficiency programs are directed at more efficient systems for space heating during cold seasons and space cooling for warm seasons. The consequences of such measures on energy use, and hence on greenhouse gas emissions, will be sensitive to changes in ambient climates. For example, warmer winters will reduce the demand for space heating. A changing climate will also have consequences for the return on investments for efficient space heating technologies. Likewise, hotter summers will increase space-cooling demands and thus increase the economic benefits of efficient space cooling technologies. The regional characteristics of climate change are therefore important in assessing the economic viability of such measures, and need to be predicted with greater accuracy.

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16. *Agricultural and Landfill Measures*. Many of the sources of methane and nitrous oxide involve biological processes in agricultural systems and in landfill sites. The processes that govern these emissions are not well understood. Hence the consequences of measures aimed at reducing these emissions are difficult to estimate. These measures include options for manure management, the application of nitrogen fertilizers on agricultural fields, and the collection and processing of gas emissions from landfill sites.

17. *Geological Sinks*. The petroleum industry has proposed injecting carbon dioxide into oil producing and uneconomic or depleted reservoirs to sequester carbon deep underground. While potential exists, there is also inadequate understanding of the longevity and magnitude of carbon sequestration using this technology.

Weyburn Carbon Dioxide Project

PanCanadian Petroleum plans to begin injection of carbon dioxide into its Weyburn Field in southeastern Saskatchewan in the fall of 2000 as part of an enhanced oil recovery project. This initiative could be employed to sequester carbon dioxide in producing oil reservoirs and uneconomic or depleted reservoirs. PanCanadian estimates that a total of approximately 20 million tons of carbon dioxide will be permanently sequestered underground over the remaining 40-year life of the field.

An extensive monitoring program is being considered for implementation at the project site to improve scientific understanding of this technology. The monitoring program would also verify the quantity of carbon dioxide sequestered, identify methods to improve the safety of carbon dioxide injection, and provide information required to increase the public acceptability of underground sequestration of carbon dioxide.

Summary

18. With appropriate coordination and resources, climate system science will significantly contribute to informed negotiations and implementation of mitigative measures under the Kyoto Protocol. Such research will need to address two distinct aspects of mitigative response.

19. The processes by which carbon can be sequestered within Canada's ecosystems. Coordination of this research must be improved, and additional, sustained resources for related systematic observations, analysis and modelling of how these processes respond to human interference under a changing environment.

20. The implications of climate change for proposed measures for mitigation. Many of the initiatives proposed as options for reducing Canada's greenhouse gas emissions are sensitive to a changing climate and other environmental factors. More research is required into these sensitivities and related implications for the NIS.

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Options Papers from the Sinks, Agriculture and Forestry Tables

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Chapter 4. Impacts and Adaptation - Developing an Evolving Strategy:

Changing Perceptions

1. Our climate is currently changing. Furthermore, it is now widely accepted that even after introducing significant mitigation measures, we will still experience some additional degree of climate change and that this will impact Canada and Canadians. There will be both positive and negative impacts. Comprehensive adaptation strategies must complement mitigative actions so as to minimize the potentially negative impacts, and to maximize the opportunities that will arise from such change.

The Kyoto Protocol and the United Nations Framework Convention on Climate Change

2. The Kyoto Protocol and the UNFCCC have explicit requirements for "Parties" relating to impacts and adaptation work, reporting and principles.

   - From the Kyoto Protocol, Article 10b:
     ...formulate, implement, publish and update national and regional programs containing measures... to facilitate adequate adaptation to climate change.

   - From the UNFCCC, Article 4:
     ... co-operate in preparing for adaptation for the impacts of climate change.

     ...take climate change considerations into account to the extent feasible in their relevant social, economic and environmental policies and actions.

   - From Article 2:
     `The ultimate objective...[is to] stabilize greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with the climate system. Such a level would be achieved within a time-frame to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.'

3. Thus, impacts and adaptation researchers (including socio-economic researchers) have substantive roles in defining what are suitable stabilization levels and rates of change. Dangerous interference cannot be defined on the basis of climate system science alone.

4. Concern over the potential impacts of future climate, including future climate extremes, is driving the national and international response to climate change. Knowingly or not, Canadian society adapts to current climate conditions, albeit in an *ad hoc* and imperfect manner. One estimate is that we already spend about $11 billion each year to do so. Part of our problem is that we continue to plan, design, and build under the assumption that our climate is quite static and unchanging. This view is not borne out by climate observations in Canada over the past 50 years or more which show very distinct trends.

5. Climate change has direct and indirect adverse effects on human health. For example: severe heat waves kill frail infants, elderly people and those with pre-existing heart and lung diseases. Extreme weather events, e.g., floods that disable sewage treatment plants, can lead to epidemics. Insects and other disease vectors proliferate in warm, moist environments and waterborne disease pathogens flourish in warmer lakes, rivers

and coastal waters. Dangerous mosquito-borne diseases (virus encephalitis, dengue and perhaps malaria) that are rare or non-existent in Canada now could occur increasingly often. Rising sea levels, floods and severe droughts displace large numbers of people ("environmental refugees") whose emergency care can stretch public health infrastructure beyond acceptable limits.

6. In order to achieve cohesive and positive adaptation we cannot continue to adjust only in an *ad hoc* and autonomous manner to climate change. Autonomous adaptation tends to be re-active, happening after some damage has occurred, and thus incurs avoidable risks, costs and losses. Pro-active planning and design in advance of the changes (anticipatory adaptation) is required. This can significantly reduce costs, and realize benefits. It is also helpful in the management of current risks. Thus there are benefits to taking action today to deal with climates of the future. There are costs to inaction, as options and/or opportunities can become more limited with time. We must carefully assess our options today. Where appropriate, such action must involve different levels of government.

7. In a simplistic sense, the choice the world will have to make for its future is, at what level will atmospheric greenhouse gas concentrations stabilize, and when. In reality, it is likely that this target may require constant or frequent adjustment and become instead a long- term target that we move toward. The implication is that the adaptation process will be an evolving and developmental response to the anticipated impacts of a changing climate.

Understanding Climate Change Impacts

8. The impacts of climate change may be classified as either physical, social or economic. They will occur in all areas of Canada. Climate system science must be used to inform impacts and adaptation research. Our confidence in the appropriateness of any adaptive strategy to redress or take advantage of these impacts is only as good as the weakest of the assumptions upon which the estimated impact is based. Definition at the local level, of the magnitude, frequency, duration, suddenness and areal extent of future climatic variations is a fundamental consideration. Unfortunately, it may be years before we have a high degree of confidence in regional climate models and how they deal with the above outputs.

9. Furthermore, we can only determine the impacts to which we will have to adapt if we fully understand the climatic sensitivities of the systems for which adaptive strategies need to be devised. While determining these sensitivities requires an intensive research program, it does not require prior detailed knowledge of future climate change.

10. Thus we must improve our knowledge in both climate system science and impacts and adaptation. A long-term goal is the development of reliable integrative modeling capability that combines climate model output with, ecosystem models and socio-economic models.

11. We already have sufficient knowledge of the likely direction of future climate change and the resultant broad scale impacts to commence a meaningful and needed program. The impacts of climate change are already apparent in some regions of the country. Permafrost is thawing in the western Arctic. Sea ice is thinning. Drought is an ongoing concern in some parts of the Prairies. Sea level rise and storm surges are already significant issues in Atlantic Canada. In western Canada, forests are being weakened by drought. Across the country, there is evidence to suggest that forest fire

frequency is increasing, and communities are having to deal with extreme flood events. These situations are consistent with the types of change that we expect to see continue and increase in the future. We can begin to undertake adaptive measures today.

12. To facilitate this, impacts and vulnerabilities resulting from historic and current climate (and other) trends need to be investigated in more detail. In some cases these trends are likely to continue for at least the immediate future (20 years or more). For example, in the Halifax area sea level is rising at a rate of about 40cm/100 years and is likely to continue. Such "scenarios" must be combined with climate scenarios of future climates as they are developed from Global Climate Models (GCMs) and Regional Climate Models (RCMs) in considering future impacts.

13. There is a need to move quickly to develop information on system (ecological, social and economic system) response to climate change. A key activity in this research will be to define sensitivities, vulnerabilities and critical climatic thresholds for key species, and systems as a whole. At what water temperature will lakes no longer support trout? Under what precipitation regimes will certain crops no longer be viable? Under what climate conditions will the geographic scope of certain vector borne diseases spread? If we have such answers then we will have a good indication of regional responses to probable future climates and some concept of when dangerous interference may occur. We also must monitor impacts as they occur.

14. Priority research needs to involve detailed case studies in representative "communities" in these regions to analyze what the current impacts of this change are; and what our regional adaptation options could be in response to the impacts we are already seeing. In what areas can we reduce our vulnerability to climate change? We can immediately commence this research based upon our current knowledge.

15. For the foreseeable future one of the major drivers defining targets for the climate modelers will be the "impacts and adaptation research community". If the latter can identify critical ecosystem or social economic system climatic thresholds at either the national or regional level, then the onus will be on the modeling community to identify the probability of those climatic thresholds being exceeded and determining when. With such information we can develop risk based adaptation responses.

Who will be affected by climate change?

16. Virtually all sectors of the economy and society as well as the broader physical and ecological environment will be affected by climate change. The following (listed alphabetically) are some of the major sectors in which adaptive responses will be necessary to deal with the impacts of climate change:
    - Agriculture
    - Communities/Municipalities
    - Ecosystems (biological environment)
    - Energy
    - Fisheries and Aquaculture
    - Forestry
    - Infrastructure (including utilities, waste, pipelines)
    - Human Health
    - Landscapes (physical environment)
    - Light and Heavy Industry
    - Transportation

- Tourism
- Water Resources

17. Each of these sectors will be affected in different ways, and not all of them will be able to respond with equal effectiveness. As well, extreme events and emergency preparedness will be a continuing issue. Expertise and capacity to deal with the issue of climate change must be multidisciplinary (physical sciences, life sciences, social sciences) and multi-sectoral (government, academia, private sector). There are national and international aspects that must be kept in mind, however, there are regional considerations as well.

18. Since the impacts of climate change will vary considerably from place to place and sector to sector, responses will tend to be focused at the local or community level. For this reason, it will be difficult to roll up sector impacts and adaptation options as though they apply as a suite to the country as a whole. This is too simplistic. This work must also have a regional focus. Thus efforts must be made to build not only national but regional expertise and to coordinate/facilitate actions.

Where do we focus first?

19. Within the bounds of our current knowledge of future climate changes, with optimal funding levels and the necessary research capacity we would be able to address the potential impacts of climate change and conduct case studies to develop adaptation strategies for all major sectors and regions of Canada. With less than optimal funding and more limited capacity we would have to focus upon key sectors and regions of the country that are already experiencing significant impacts and which are most at risk.

Phased work program

20. Whatever the scope of the program, it must occur in stages, while the results of the work program must be delivered in such a way that regional variations may be extracted in order to provide the basis for discussion of national, regional and local implementation.

21. For each topic/sector, under each of the options, a phased work program should answer the following questions dealing with impacts and adaptation:

a. What are the climatic impacts (positive and negative) to which sectors will have to adapt?

- What is the anticipated magnitude and rate of change in climate to which sectors might be exposed?

b. Who (which sector/region) is vulnerable?

- What is the sensitivity of that sector or region to potential climate change? What are the likely impacts and can it adapt (i.e. vulnerability)? What is the regional variation in both the sensitivity and vulnerability of the sector?
- What are the cross sectoral and cross regional issues involved? By assessing the levels of sensitivity of various sectors to climate variability and change we can identify priorities for action.

c. What is the objective of adaptation?

(ie, given the potential impacts, what do we strive to achieve through adaptation?)

- Can we reduce the vulnerability to climate change?

- Will a particular adaptive response buy us only a few years' grace, or will it give more permanent protection? By knowing this, we can target our efforts more efficiently and economically.
- By adapting, what will we gain and what will we potentially lose; are there synergistic or conflicting issues?

d. How well are we adapting already?

- What has been tried in various circumstances to date, since there has been adaptation to past climatic extremes or variations (i.e. what do we know now?).
- What roles did individuals, corporations, municipalities, provincial government, and federal government play?
- What were the barriers to adaptation and were they (can they be) removed? What are the other drivers affecting the sector or region (population, industrial shifts, resource markets).

e. What else do we need to know - what do we need to do to achieve that objective?

- What are the social components (gains/losses) associated with needed decisions: dislocations, loss of a way of life, regional disparities, (including environmental consequences), regional opportunities and how to take advantage of them.

f. What will it cost, for what benefit?

- What is worth doing? What value do we put on each?
- What is the overall cost-effectiveness of the potential mix of measures that might be introduced? Are we willing to accept some impacts? There may be some impacts for which there are no adaptation options (other than accepting them) what are these and what value do we place on them?
- Is there co-consideration of mitigative and adaptive strategies at, for example, the community level? Some mitigative strategies may support or enhance the scope of adaptive strategies while others may prevent their introduction.

Priorities for Research

22. There is a need to follow on from the Canada Country Study to further clarify the impacts of climate change on Canada and to develop adaptation options. Although further research is needed to better identify the critical foci, on the basis of work completed to date, sectoral reports, and workshops and consultations, if less than optimal funding were available then focusing upon the following sectors would seem to give the greatest and most immediate return:
    - Municipalities/Infrastructure (having significant input from, for example, the insurance industry)
    - Water Resources
    - Food Supply (would include Agriculture, Fisheries and Northern wildlife)
    - Human Health
    - The Coastal zone (encompassing both infrastructure and livelihood)
    - Forestry

23. Of these sectors - it is suggested that concentrating on municipalities may bring the most immediate and widespread benefit. Thus the above selected sectoral list, led by municipalities, forms a priority list for research. Also, because of its vulnerability, there should be a specific focus on these issues and sectors in northern Canada.

Technology

24. The adaptive response to potential climate change impacts may be behavioural, administrative or technological. There may be commercial opportunities if such technologies come into widespread use at home or abroad. However, it may take several years to identify where the greatest potential lies. Will solar powered pumps become both useful and popular in drought prone areas? The needs for technological solutions will be defined, not only with respect to the primary objective of communities, but also in areas such as aquaculture, biotechnology, satellite-aided farming, flood control structures and water conserving irrigation systems. As well, there will be an identification of the mechanisms needed to spur innovation needed to address adaptation, from research & development to market readiness both for domestic and international needs.

Canadian Climate Impacts and Adaptation Research Network (C-CIARN)

25. In order to meet the challenge and to complete the research needed, it is proposed that C-CIARN be established to coordinate impacts and adaptation research in Canada and to provide a better focused research and assessment capability. There is a need, on a systematic and ongoing basis, to:
    - Develop and communicate a nationally (i.e. spatially) consistent picture that reflects the regional and sectoral differences and needs in impacts and adaptation research;
    - Examine and consider cross sectoral and cross regional research issues and synergies;
    - Provide, on a periodic basis, national assessments of the current state of knowledge of the impacts of climate change on Canada; and
    - Address the international aspects of impacts and adaptation.

    This network will link university, federal and provincial researchers and important stakeholders. It will build on and complement existing sectoral and regional efforts.

26. C-CIARN would consist of a series of nodes representing key regions and sectors. It is anticipated that there may be 6 regional and 10 sectoral/topical nodes. At a minimum each node should be led by a principal investigator, supported by one person. Each PI would be responsible for leading the coordination of the impacts and adaptation research for their area of responsibility (a region or sector) and for representing that region or sector in the overall management of the network operation. A national coordination office would support the day-to-day functioning of the network. That office would also support the Board of Representatives who will set the direction for the research and liaise with the national climate change process.

Research Capacity

27. The ability to carry out the program required on impacts and adaptation is limited by the current research capacity within Canada and around the world. In comparison with the worldwide focus on mitigation and energy conservation, impacts and adaptation research in Canada and elsewhere is largely in its infancy. Few research institutions in universities, government and industry are focused on the issue of adaptation to climate change. New funding is required to build sectoral, regional and integrative capacity in Canada.

Partnerships to build capacity

28. One capacity building model that could be considered is a cost-sharing process. With new funding under the NIS, universities would create a new position in impacts and adaptation research that would be eligible to apply and compete for additional funds to support a second researcher (up to a maximum of $50K per year for 5 years). Similarly, government institutions would be encouraged to enroll existing staff in programs directed towards impacts adaptation research by offering to support a second researcher (up to a maximum of $50k per year for 5 years). A separate fund would be established for each of the two cases. Competition for the funding would be based on the relevance of the proposed research to the needs identified.

29. Additional incremental funding would be allocated to the Granting Councils (medical, natural sciences and engineering, social sciences and humanities) to fund studentships and post-doctoral fellows in impacts and adaptation research. Funding would be tenable at any institution conducting research in that area (not only universities and government institutions, but also in industrial laboratories whose work is freely published).

30. The investment made in developing new researchers and in redirecting researchers will be realized in advances in understanding impacts and developing adaptation options in each of the sectors identified above. This is an investment that must be made, given the long-term nature of the problem.

Domestic Considerations

31. Clearly a range of funding is possible. Eventually all sectors and regions of the country must be covered as is identified under the optimal funding option. At less than optimal funding levels, the focus of the work in each of the above sectors will vary with the funding levels available.

32. The operating principle used is that with less than optimal funding and limited capacity, a staggered program will be initiated that focuses upon fewer sectors than in the ideal case. It is likely to be both more realistic and productive to focus on fewer sectors, than to spread our effort equally amongst a wider range of activities in a manner that would yield less than adequate results.

33. For each of the six key sectors identified, with only threshold funding a major focus would be on the Municipalities sector, the other sectors being covered to some degree. With optimal funding all sectors would be addressed. With intermediate level funding, more detailed work and case studies would be carried out on the six sectors identified.

34. Work on impacts and adaptation must be must be completed and reported on as part of the UNFCCC and the Kyoto Protocol.

International Considerations

35. Although climate impacts and adaptation are primarily a domestic concern, there is a significant international dimension as well. Our economic systems are linked to the global economy. The differing impacts of climate change around the world and the adaptive actions taken will be an important influence, as will the international ramifications of our adaptive actions. This is particularly true along our borders with the USA and in the Arctic where Canada shares a special responsibility with our circumpolar neighbours.

36. If we are to influence international policy and science as it relates to impacts and adaptation research then we must have strong participation in the IPCC.

37. As a donor of international aid, Canada will inevitably need to deal with the consequences if developing countries do not (or are unable to) adapt successfully to climate change. Many of these countries often lack the infrastructure that will be needed to adapt to many of the climate change problems they will face. Developing countries have identified adaptation as a major concern. It is therefore in Canada's interest to assist them in the task of adaptation and the enhancement of their adaptive capacity.

38. With minimal funding, except for participation in the IPCC, international implications will only be considered either as part of the work carried out by the impacts and adaptation sectors or though separate funding mechanisms. The upper limit to investment in international work is a political rather than a scientific decision. A paper exploring the scope of opportunities open to Canada on the international scene is urgently required; with substantive funding, work could commence at once.

Governance: Roles and Responsibilities

39. Adaptation to climate change will require socio-economic decisions to be addressed at three levels:
    - governments (public sector)
    - industry (private sector)
    - individuals

40. Responsibility for adapting to specific impacts will rest with those industries, communities and individuals that are most affected. Various levels of government (municipal, provincial and federal) can provide leadership resources and legislative authority by removing barriers and setting standards and regulations to implement adaptation strategies. As well there will be consequences for government operations and properties - governments can lead by example. The challenge is to define the various roles and responsibilities of the public and private sectors more precisely. When should governments get involved, what should they do, and what decisions and actions are best left to industries and to individuals? A process is required, not only to decide on the most appropriate adaptation strategy, but also on how that strategy will be implemented. It is proposed that an urgent element of the National Implementation Strategy is to commission a paper describing the possible options for governance of the process of adaptation. In the longer run, funding will be required both for a series of consultations and to run the process.

Summary

41. We know enough about the direction and potential general impacts of climate change to warrant an immediate start on research on potential impacts, sensitivities and vulnerabilities to climate change across Canada, this includes an assessment of the potentially positive benefits. At the very least, the program should ensure that our adaptation options remain open while we more fully address sensitivities and vulnerabilities in key sectors and assess priorities for future work.

42. There are areas of Canada where the impacts of climate change are already occurring. These are key areas where we can begin the process of studying impacts

and thresholds in more detail and start considering today's and tomorrow's adaptive strategies. In some cases adaptive responses are justified now.

43. We can also immediately begin the process of defining the need for technological development in key areas and identifying the mechanisms needed to spur innovation.
44. Climate change impacts and the process of adaptation will be with us for the foreseeable future. We must invest in developing our ability to adapt. We must invest in developing our capacity to do this work, to co-ordinate and facilitate it (i.e. develop C-CIARN) and to manage the implications inherent in implementation, especially where cross border jurisdictions are involved (i.e. consider issues of process).

45. As this area of research is relatively new, the extent of the program would be largely controlled by the funds invested in it. Recommendations and funding requirements are covered in Chapter 7.

Recommended reading

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Smit, Barry, *Agriculture Adaptation to Climate Change,* Report prepared for the Adaptation Liaison Office Natural Resources Canada, 1999.

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Andrey, Jean and Brian Mills, *Adaptation to Climate Change in the Canadian Transport Sector,* Report prepared for the Adaptation Liaison Office, Natural Resources Canada, 1999.

Hauer, Grant, T. Williamson and M. Renner, *Socio-economic Impacts and Adaptive Responses to Climate Change A Canadian Forest Sector Perspective*, Report prepared for the Adaptation Liaison Office, Natural Resources Canada, 1999.

*Copies of the reports prepared for Natural Resources Canada are available on the web site at: http://sts.gsc.nrcan.gc.ca/adaptation/
or by contacting the
Adaptation Liaison Office,
Natural Resources Canada
Tel: 613 943-8199
1. Fax: 613 992-0190

Chapter 5: Climate System Science - A Necessary Investment

Why Science is Needed - Science for Future Negotiations

1. Scientific effort has been used for understanding what is happening to our climate, why it is happening, what changes in the climate can be anticipated, and what impacts the change will have on our natural systems and human economy. Science will be needed to support the development of reduce greenhouse gas emissions (mitigation) and to adapt to inevitable change. It is becoming clear that under any realistic scenario of mitigation there will be significant climate change. It will be important to understand these climate changes and their regional variations and implications in order to adapt efficiently and effectively. We do need to understand how adaptive or mitigative actions will feedback on the speed and impact of climate change itself.

2. As more is learned about the impact of human activities on the climate system it can be expected that agreements such as the one concluded in 1997 in Kyoto will be refined and renegotiated. It will be vitally important for Canada to maintain a high level of expertise in climate system science, modelling and analysis to inform those negotiations and enhance our credibility. The history of the agreements on stratospheric ozone depletion may provide an instructive analogy. Under the original Montreal Protocol, the level of ozone-depleting chemicals in the stratosphere would have continued to rise at a rate not much less than that of a business as usual scenario, yet that is all that nations were willing to commit to initially. Subsequent amendments, made in the light of accumulating scientific evidence of the need for stronger action, remedied this. It took several rounds of negotiation but nations eventually agreed on the much stronger measures now in place. The climate change issue seems to be on a similar track. However, the actions required to reduce the emission of greenhouse gases will be much more difficult and disruptive than those required to control the emission of ozone depleting chemicals, so it will be even more vital to be well informed. The negotiations can be expected to be protracted, repeated and difficult. Climate system science will play an essential role.

3. The climate system is global and we know that climate change will not be a simple warming. Some areas will warm much more than others and some will actually cool. Even more importantly, variability and the frequency of extremes will change and these changes will be local. We have much at stake as stewards of the northern half of the North American continent and its adjacent continental shelf and marine resources, areas where the impacts are already predicted to be large. We require the capability to calculate for ourselves local climate changes and to see the risks to our natural ecosystems and resource dependent socioeconomic activities.

4. The kinds of science that will be needed will include augmented systematic observations, research on and modelling of the climate system, the production of climate change scenarios and research on the impacts of climate change on natural systems, the human economy and human health. In order to assess options for adapting to or mitigating climate change impacts we will require effective tools for better integration of scientific knowledge into policy-making fora. We will have to develop models for an integrated assessment of various adaptation and mitigation options.

Systematic Observation of Climate

5. The characterization of past and current climate provides the basis for assessing Canada's future climate and its changes. We must describe the mean state and natural variability of the present climatic regime before any human induced climate

change can be found as a residual signal. This necessitates long-term routine systematic observation of key atmospheric, oceanic, hydrologic, cryospheric and terrestrial variables, using techniques that not only determine average conditions but also yield information on rates of change and on extremes. It requires that observations be representative, free from extraneous influence and free from long term drift. They must be quality assured, documented, archived and made readily accessible, all in accordance with international standards. Although remote sensing can provide excellent spatial coverage of many climate variables, the continuing use of in-situ observation remains vital, both for ground-truthing of remotely sensed observations and to provide data that cannot be obtained in any other way. Large parts of Canada have suffered a decline in coverage of *in-situ* observations, to the point where internationally, our data programs have fallen below acceptable standards in terms of our ability to define the climate.

6. Canadian atmospheric monitoring programs reflect a balance between affordability, practicality and ability to respond to needs on a variety of scales. Consequently, climate-observing networks are most dense where population and economic activity are greatest. But they are well below internationally recommended standards in the northern two-thirds of the country. As a response to these shortcomings a federal program called the Climate Reference Network has been identified to provide stable, homogeneous, long-term, observational data. Automatic stations now enable us to obtain at least some observations nearly anywhere and, as a result, the spatial distribution of climate observing networks can be improved. The capabilities of satellite remote sensing programs are expanding. These positive measures need to be strongly supported in order to ensure our domestic capacity and meet Canada's international commitments.

7. With the world's longest coastline, Canadian interests include three neighbouring oceans. Existing Canadian ocean observing programs are very limited in scope, and are not designed or maintained as a climate observing system. Observations from coastal buoys, the tide-gauge network, meteorological observations from vessels plying our economic zone and a few long-term oceanographic sections and stations represent the only systematic efforts. Canada's long term observations at single sites in the North Pacific, Beaufort Sea and Labrador Sea as well as its research programs in these same regions show that these regions have experienced strong variability over the past few decades. A continuation and expansion of these observations is needed to determine whether indeed this is climate change and to predict its impacts. A national ocean observing system that simultaneously meets domestic needs, responds to our international commitments and contributes to the internationally developed plan for ocean climate observations is required. Canada will also need to implement observations focused on the impacts of climate change on our shelf and inshore waters.

8. The response of water resources will be a critical factor determining the environmental, economic and social costs of climate change to Canada. It is, therefore, important that our hydrological observing programs have the capacity to monitor and detect climate induced changes in the hydrological cycle. Remote sensing and modelling are receiving increasing emphasis as a result of reductions to in-situ measurement programs. Remote sensing can be used for national assessments of surface waters, in particular lakes and wetlands, and provides a means of improving the hydrological database. Similarly, hydrologic modelling can be applied to estimate the major hydrologic variables, as an alternative or supplement to direct measurement.

9. The cryosphere includes ice sheets, ice shelves, ice caps and glaciers, sea ice, seasonal snow cover, lake and river ice, and seasonally frozen ground and permafrost. It is an integral part of the global climate system, influencing surface energy and moisture fluxes, clouds, precipitation, hydrology, and atmospheric and oceanic circulation. Consistent, long-term information on cryospheric variables over a range of spatial and temporal scales is required for climate change detection. Canada is uniquely placed to provide necessary data on the cryosphere and indeed has an international obligation to do so. There is a need to improve access to and exchange of Canadian cryospheric data sets. Additional efforts are also required to fill spatial and temporal gaps in data records through integration of in situ data, physical models and remotely sensed information.

10. Very few Canadian terrestrial ecosystem observing programs collect extensive, long-term data sets to sufficiently high standards to track climate change and its effects on managed ecosystems such as forests and agricultural lands, and especially its effects on plants and animals in unmanaged ecosystems. There is, furthermore, no network of terrestrial sites that provides long-term records of climatological data in conjunction with terrestrial vegetation observations. In particular, observations are required from transition zones and climate sensitive ecosystems such as alpine tree lines, the southern fringe of the permafrost zone, coastal floodplains and the edges of prairie grassland. Shifts in forest fire patterns and trends in higher intensity and larger fires are also potentially useful indicators of climate change. More sophisticated monitoring of fire occurrences and patterns will provide a basis for relating long-term climate trends to forest fire characteristics. By taking the fullest advantage of new remote sensing and modelling technologies it should be possible to design a terrestrial ecosystem monitoring system that meets national climate monitoring requirements as a first priority, rather than being an afterthought or an add-on to systems designed for other purposes.

11. In addition to monitoring ecosystem impacts, we need to systematically collect data on the impacts of climate and climate change on human economic and social systems and on human health. Key information such as insurance claims, crop yields, lake levels, tonnage shipped, etc. and especially the impact of severe weather events (the eastern Canada ice storm of 1998 comes to mind) needs to be gathered and preserved.

12. The issue of inadequate access to climate data in Canada comes up time and again when talking to researchers. Government cost recovery policies should be reviewed to make sure that they do not pose unnecessary barriers to access to existing data. The archiving of climate data is so highly fragmented that it is difficult to find out what datasets are available, let alone how to access them. The existence of data may be acknowledged but access is denied. Much climate data has been collected under the auspices of other programs and is not identified as climate data. Other datasets are regarded as the property of the researcher who collected them, rather than the research community at large.

Developing a Better Understanding of the Climate System

13. Augmented research on the climate system itself will be required in order to improve our understanding of how the system functions and hence our ability to model and predict how human activities are affecting it. We need to clearly understand the probability of change in average conditions, but even more important than this is the need to understand the probability of change in climate variability, in the frequency of extremes and the risks of severe storms, floods and droughts. There is also a risk of

climate "surprises", such as a shutdown in the North Atlantic thermohaline circulation (the Gulf Stream) the "conveyor belt" ocean circulation that keeps northern Europe warm that warrant further study.

14. Climate system science operates on several fronts. One is analysis of the past behaviour of climate as reconstructed from observations of the climate system or suitable proxies. Another has to do with building conceptual or simplified models of the dynamics and physical processes of the climate system. The final stage is to build models of the whole climate system, as nearly complete as possible, with the key processes represented to the highest possible level of fidelity, consistent with their impact on results. Canada has been an important contributor to the planning and execution of international climate system science programs since their inception in the early 1970's. We have made major contributions, in particular, to the science and technology of climate system modelling, building on a solid basis of earlier and continuing contribution to the related field of numerical weather prediction modelling.

15. The effects of the well mixed greenhouse gases on the flow of radiation into and out of the Earth's atmosphere are quite well understood, although the effect of aerosols (suspended liquid and solid particles) or short-lived gases such as ozone is much more uncertain. The understanding of the effect of aerosols on cloud properties is currently too poor to make credible estimates of their magnitudes. The responsive changes in vertical and horizontal distribution of water vapour, a very important but complex amplifying mechanism within the climate system, are as yet difficult to predict and hence a significant source of uncertainty. Likewise, the response of cloud properties and cover, changes in sea ice distribution and ocean circulation changes are important feedbacks within the climate system that are inadequately understood and are key areas where study is required in order to reduce the uncertainties in model predictions. Studies into past changes in the Earth's climate also reveals that regional climates can change abruptly, suggesting the possibility of large "surprises" in how the global system responds to increasing emissions of greenhouse gases.

16. The Canadian Centre for Climate Modelling and Analysis (CCCma)[7] has built a series of increasingly sophisticated global climate models, and has recently completed version II of a coupled ocean-atmosphere general circulation model (CGCM). However, the ability of the group to attract the additional scientific talent it needs in order to be able to incorporate all of the physical and, increasingly, biological processes of the climate systems is limited by resource constraints. As noted below, this group gets significant support from university researchers, but it requires additional professional staff in a number of new disciplines to assist with the integration of new algorithms and components into the CGCM. The original idea was to furnish the group with a dedicated supercomputer. This was not possible and it continues to share a supercomputer facility with operational weather forecasting. Continued access to the highest order of computing power is absolutely essential for this type of modelling.

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[7] The Canadian Centre for Climate Modelling and Analysis (CCCma) is a Division of Environment Canada located on the University of Victoria campus to which location it was moved in 1994 in order to facilitate interaction with ocean modellers. It is Canada's national climate modelling centre.

17. CCCma has been supported by work in other government laboratories and in the universities, notably by the Climate Research Network (CRN)[8] a collaborative research network established in 1994 and funded largely by Environment Canada. This innovative arrangement was devised in order to tap talent in the universities rather than attempt to build up in-house resources. It currently has nine nodes or major projects involving more than a dozen universities. Most of these have succeeded in attracting additional funding from other sources, notably NSERC. In this way university talent, both post-doctoral and graduate students has been developed and focused on climate issues in a way that simply wouldn't have happened otherwise. CRN research is concentrated in areas such as climate variability studies, ocean modelling (global, Arctic and North Atlantic), land surface process modelling, cloud and aerosol modelling, lake and ocean ice modelling, stratospheric process modelling, carbon cycle modelling and regional climate modelling. All of these areas are crucial for understanding and predicting climate change in Canada. In addition, the results of this research would enhance the accuracy of the global and regional modelling effort at CCCma.

18. Ocean modelling has been stimulated in the universities through the CRN, and some scientists have been involved. However, government labs are not eligible for CRN funding. Hence, there is a need for additional government funding of ocean modelling in Canada's major oceanographic institutes.

19. Increasingly, climate models will have to incorporate elements of biological systems as well as the physical systems that have been treated so far. The full treatment of the carbon cycle requires biogeochemical modelling of terrestrial and oceanic living systems that participate in the uptake, storage and release of carbon dioxide, methane and other greenhouse gases. Although Canada's human contribution to the production and burning of fossil fuels is only a small percentage of the global total, our much more significant fraction of the world's forests and wetlands could play an important global role as potential sinks of carbon. As outlined in earlier chapters, our international position would be greatly enhanced if we understood this potential for the coming rounds of negotiations on emission reductions and carbon sinks. Adding these aspects to the Canadian global climate model will require significant additional to the expertise and computer resources.

20. Regional climate modelling is still in its infancy, yet it is at the regional level that climate change impacts are going to be felt. Canada has unique circumstances, including a dependence on agricultural, forestry and marine and freshwater ecosystems that may be particularly vulnerable to climate change. We cannot expect modellers in other countries to deal with these issues. We have made a beginning in modelling these scales but only a beginning. The Canadian Regional Climate Model was developed at the University of Quebec at Montreal as a CRN project using elements of the CCCma global climate model. Further development of this technology and the commensurate dissemination of model results for the production of climate scenarios for impact and adaptation research, are required.

21. Climate variability is becoming better understood, especially the role of quasi-cyclic oscillations of the ocean-atmosphere climate system such as "el Niño/ la Niña". These

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[8] The Climate Research Network (CRN) is a collaborative network of university based researchers working on problems related to improving climate modelling. It is funded through a research contribution program managed by the Canadian Institute for Climate Studies, a non-profit Canadian corporation also located on the University of Victoria campus.

cycles have ramifications for regional climate throughout Canada and, of course, elsewhere. It is at least a possibility that the global climate system will respond to greenhouse gas forcing by spending more time in a particular phase of such oscillations. The future climate may look something like a quasi-permanent el Niño, for example. Our knowledge is still in its infancy on these matters and on the related question of carbon uptake and release by the oceans as a function of temperature changes and the feedback of that on climate change.

Greenhouse Gases and Sinks

22. The processes that determine the direct emissions of greenhouse gases from most industrial sources, such as that of CO_2 from the burning of fossil fuels, are in general reasonably well understood and hence can be estimated with considerable accuracy. However, emissions from sources involving biological processes, such as methane from livestock, manure, landfill sites and hydroelectric reservoirs or nitrous oxide from cultivated soils are highly variable in space and time and are much less well understood. Hence, if policy makers are to have a better grasp of how options to reduce greenhouse gas emissions will help meet future targets, the processes involved need to be further investigated and understood, and appropriate models developed or improved to simulate how these processes will contribute to emissions under varying conditions. This is particularly relevant for Canada, since it is responsible for a disproportionately large share of the global terrestrial landscape.

23. A significant fraction of the greenhouse gases released by human activities into the atmosphere each year is removed again by natural processes. For methane, for example, chemical processes remove most of the excess gas released, while about 50% of human carbon dioxide emissions are removed by photosynthetic and absorption processes into ocean and terrestrial systems. These processes are sensitive to climate and other environmental conditions and can vary from year to year and location to location. Knowledge of how these removal processes may change in the future as the behaviour of the global climate system changes is important to how rapidly greenhouse gas concentrations will increase in response to future emissions. Furthermore, climate change can also be important in increasing or decreasing natural sources of greenhouse gases. This is particularly important for carbon dioxide, since natural emissions are more than an order of magnitude greater than human emissions. While international research has helped improve the understanding of many of these processes, it is still not fully understood how some of the human emissions are removed and where they are accumulating. Future predictions of the consequences of greenhouse gas emissions are based on physical and chemical models that attempt to simulate how the natural cycles of various greenhouse gases will change as climate warms, ocean circulation changes, and CO_2 fertilization of plants increases. Much of the related research in improving these models is conducted within Canada's forests, wetlands and adjacent oceans. However, there is currently no sustained program to integrate all the research, reduce the related uncertainties and improve the predictions of how human emissions affect concentrations. There is also limited understanding of how sequestration of carbon by vegetation and soils might be increased by human intervention in order partially to compensate for human emissions.

Climate Scenarios

24. Climate impacts depend on the vulnerability and sensitivity of the system effected. Research on climate impact and climate change adaptation requires scenarios of possible future climate on scales and including variables, most important for the natura

climatological information on both the current and future climate would benefit the research community. More work is needed on sophisticated interpolation techniques capable of incorporating topographic effects, for example, in order to produce high-resolution climatological fields from the low-resolution long-term observing station network.

25. There is also a requirement to make available to the research community: i) modern climate data sets including frequency analysis of extreme events; and ii) paleo-environmental reconstruction for recent past-climates to guide or inform discussions of the potential range of impacts.

26. The community that does climate impact studies includes scientists in many disciplines. They are not used to dealing with the raw output from climate prediction models. Nor are they necessarily aware of the pitfalls to avoid when using modelled scenarios. There is currently no interface that translates their requirements into a specification that can be understood by climate modellers and that in turn provides the impacts community with information on the prudent use of climate scenario information. Such a facility could obviously accelerate climate impacts studies and the development of adaptive options. Other nations are setting up similar mechanisms to do this.

Integrated Assessment and Integrated Assessment Modelling

27. Credible climate scenarios require credible estimates of greenhouse gas emissions and future concentrations. To date these have been specified as external to climate models. Ultimately, as will be discussed below, they will need to be made an interactive part of "integrated assessment models".

28. While scientists, through continued research, can generate knowledge on the different aspects of the risks of climate change and its impacts, there is also a need for interactive tools that can integrate these different elements into a simple comprehensive picture for discussions between scientific experts and policy makers. A number of these tools are now under development within the international research community, but there is minimal related expertise in Canada. These tools have individual modules representing the elements of the climate system dealt with in this Options Paper. In terms of the climate system, simplified climate modules that do not need large super computing resources and can be run much faster are being developed. In addition, modellers are beginning to develop models of how the changing climate impacts ecological processes and how they in turn feed back through changes in the cycles of carbon dioxide, methane and nitrous oxide. Some countries are beginning to connect such climate models to economic models that can begin to include the human, economic and social costs and benefits of climate change, adaptation and mitigation. In this way for large areas different scenarios of directed adaptation and mitigation can be examined in the context of their feedbacks to the climate system and hence of the anticipated changes in the climates. Little is happening in the area of integrated assessment modelling in Canada although the elements exist and some proposals have been discussed. This is a significant deficiency in developing Canada's policies for adaptation and mitigation and supporting our negotiating positions.

Summary

29. Resolutions adopted by the Conference of the Parties within the FCCC have stated that the decline in long-term systematic observation must be reversed. *In-situ* networks have to meet international standards for density and quality of observations. Particular

attention needs to be paid to the Canadian Arctic where all components of the climate observing system are well below requirements and in some cases non-existent. The monitoring of climate should be recognized as a priority in the mandates of agencies that have carried on programs in a piece-meal fashion using research funds or as an add-on to other programs. This is particularly true of the oceans and the cryosphere. Canada has an international responsibility and national need to contribute to the global ocean observing system and consistently monitor its own coastal and Arctic waters, as outlined in detail in the National Plan for Participation in GCOS [9]. Monitoring of terrestrial ecosystems and their reaction to climate change is a particular need everywhere in the country. Greater advantage of modern techniques for automated observing platforms and satellite communications, remote sensing and numerical modelling and data assimilation for the integration of *in-situ* and remote observations should be considered in order to make Canada's systematic monitoring system as cost-effective as possible. Establishment of a Canadian Board for Systematic Climate Observation is needed in order to coordinate the efforts of the many agencies involved in climate observation. Such a board should be charged with improving the archiving and accessibility of climate data.

30. The Canadian Centre for Climate Modelling and Analysis, the unit that integrates the advances in understanding produced by the Climate Research Network, (the effective and most visible demonstration of Canada's commitment to climate system science) needs to be strengthened and expanded. The modelling capacity, particularity that of the oceans, needs significant enhancement. A lack of resources and modern facilities for much of the needed work on climate system issues has made it difficult to retain our own scientists, to hire world-class researchers and to train the next generation of climate system scientists. Canada's proven strength in numerical modelling of the climate system should be built upon and augmented. Global coupled atmosphere-ocean models, the elimination of flux adjustments and the treatment of sub-grid scale processes in the atmosphere and ocean components requires refinement. Significant additional work on regional climate modelling, modelling of clouds and their radiative feedbacks and modelling the carbon cycle is needed. Data assimilation techniques, particularly for ocean climate data but also for other components of the climate system, can maximise the efficiency with which climate data is treated. Research into changes in the frequency of extreme events, using both the past record and climate model predictions is just beginning. That work needs to be linked to work on the vulnerabilities of natural and human systems in order to calculate the potential in risks. The risk of climate surprises due to "regime shifts" of the climate system, as certain critical thresholds are passed is a significant threat that needs to be better defined. Canada has been a strong participant, in keeping with our economic standing and our geographic stake, in international climate system science programs. We have benefited considerably both in terms of understanding better our own climate and the anticipated changes and in enhancing our credibility in international negotiations.

31. A group with responsibility for the production and dissemination of climate scenarios, acting as an interface between the climate modelling community and the impacts community, should be created. Scenarios based on extrapolation of past trends and on predictions from will enhance climate change policy development in Canada.

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[9] see "Recommended Reading"

32. Canada must begin the task of building integrated assessment models of climate, ecology and human economy taking account of non-linear interactions and feedbacks among all components of the climate system.

Recommended Reading

The Case for Canadian Contributions to the Global Climate Observing System (GCOS). Report to the Canadian Climate Program Board and the Canadian Global Change Program Board, May 5, 1995.

Report on the Adequacy of the Global Climate Observing Systems. UNFCCC, November 2 - 13, 1998, Buenos Aires, Argentina.

Draft Plan for Canadian Participation in the Global Climate Observing System (GCOS). Final Report under Contract No. KM040-8-6683, prepared for Climate Research Branch, Atmospheric Environment Service, 4905 Dufferin St., Downsview ON Canada M3H 5T4 by the Canadian Institute for Climate Studies, 130 Saunders Annex, University of Victoria, PO Box 1700, Stn CSC, Victoria BC Canada V8W 2Y2

Climate Scenarios for the Canadian Impacts Community ÿ Identifying the Needs. Report on a workshop held 27-28 May 1999 at Ste-Adele Quebec, prepared for the Environmental Adaptation Research Group, Atmospheric Environment Service, 4905 Dufferin St., Downsview, Ontario M3H 5T4 by Climate Research and Consultancy, 2256 King Street, Regina, Saskatchewan S4T 4H1

Chapter 6: Making Informed Decisions

Context

1. All Canadians will be faced with perplexing, complex and difficult decisions as they consider policies and actions on mitigation and as adaptation strategies take shape. We have shown that it is necessary for these decisions to be based on sound science. We believe it is vital for Canadians to understand the science; what is known and what is uncertain. We believe there is also considerable risk of confusion since there are potential overlaps and conflicts in how each sector of society might seek to move in the future, both with respect to mitigation and to adaptation.

2. In order to optimize analysis for decision and minimize confusion, it is essential for the federal government to ensure that all Canadians have clear, consistent, unbiased and sound information on which to base their decisions. Moreover, we believe that such information must be delivered and presented to Canadians in a manner consistent with their ability to comprehend the science.

3. Because of the critical importance of a well-designed Public Education and Outreach (PEO) program to public policy and action on climate change, we are including recommendations for PEO as it pertains to the climate system science, impacts and adaptation agenda.

4. We recognize the importance of ensuring that climate change public policy under consideration by the federal government be developed with the best scientific advice available and offer a specific recommendation to achieve that goal.

Principles

5. There are a number of important principles related to public information programs on climate system science, impacts and adaptation.

Need for a Long Term View

6. The world is learning about climate change. Canadians will be continuously learning as science and experience provides us with increased understanding over time. There is therefore a need for long-term investment in PEO programs. Canada's approach to PEO on climate system science, impacts and adaptation should be based on this principle and leave an ongoing legacy.

7. As science evolves and we acquire improved understanding of how the climate system operates, Canada will need to refine its greenhouse gas emissions reduction and adaptation actions based on this new understanding. Such refinement will likely require additional changes in the lifestyle of Canadians. Adaptation options and strategies will also change as more is learned about the impacts of a changing climate. By laying a firm foundation now, it will be easier later to present new scientific information to motivate Canadians to make the required changes.

8. The long term nature of the climate change issue also makes it necessary to plan for regular reviews of any PEO programs and to measure Canadians' understanding of and attitude towards climate change

More than Greenhouse Gas Reductions Policies

9. Much of the existing effort to provide advice to government on climate change policy has correctly been focused on the difficult issue of global greenhouse gas reductions. Canadians should be urged to learn about the potential impacts of climate change - both positive and negative. Impacts and adaptation should be included as a priority in PEO policies and programs. Canadians should understand that greenhouse gas reduction is a vital goal but not the only goal.

Environmental Benefits of Action

10. Canadians will be invited to take action to help reduce the risk of negative impacts of climate change. Many of the required actions will have general benefit to the atmosphere we all breathe and to the environment. Indeed, these other benefits may be more persuasive in having Canadians take action. Canadians take action. There are areas where the changes we are seeing today are consistent with the changes we expect in the future (as detailed in Chapter 2). We will benefit by dealing with these issues today. Such benefits should be highlighted for Canadians in the government's PEO programs.

Uncertainty and Risk

11. Science has told us that man is influencing the climate of the earth. Science cannot yet tell us in detail about the impacts resulting from a changing climate where and when this will be significant for example and that, in and of itself, should be enough cause for concern and participation on all fronts. It is particularly the uncertainty about climate system science and impacts that has many people unsure regarding what they are dealing with. Canada's PEO programs should take this uncertainty into account.

Minimize Overlapping and Confusing Messaging

12. Increasing information on climate change is available to the public. There is a danger of "information overload" for the public with climate change messages coming from all directions including those that are highlighting the scientific uncertainties and creating confusion. It is important to ensure that any public outreach program be designed to avoid overlapping and confusing messages. The messages have to simple, clear and reinforcing.

Regional Differences

13. Any PEO activity on impacts and adaptation in particular must acknowledge that there are and will be strong regional differences in the way the climate affects Canadians. Canada is a large country that experiences many different climates. Science as well as experience tells us that impacts will be different. It is therefore important for federal policy to recognize these differences.

Credibility

14. At "Opportunities for Action", a forum on climate change public outreach held in Toronto in June 1998, it was concluded that climate change is most easily communicated by those perceived as having no vested interest in the issue.

15. This need for credibility was reinforced at the National Forum on Climate Change sponsored by the National Round Table on the Environment and Economy.

16. Moreover, specific sectors and interest groups will tend to find the opinion of leaders in their communities more credible than that of "outsiders". It is therefore important to recognize the value of credible sources and multipliers of information.

The Important Role of the Media

17. The public and most decision-makers will continue to get their information on latest developments from media sources that are often themselves biased towards controversy or are uninformed about the science. PEO policies on climate change must pay particular attention to meeting the needs of the media for balanced, up-to-date, understandable and credible scientific information.

Matching Messages and Delivery Mechanisms to Audiences

18. In general, communication programs structure their themes, messages and delivery approaches to fit the context and the intended audience. Because of the complexity, scope, uncertainty and longevity of the climate change issue, it is of particular importance to carefully structure long- term PEO programs regarding climate system science, impacts and adaptation with specific audiences in mind. The need for "appropriate" communication is paramount, particularly for the policy community at different levels of government.

Interpersonal Approach with Leaders, Decision Makers and the Policy Community

19. Climate change related science is complex and relatively new for many leaders and policy makers in Canadian society. An interpersonal and interactive approach, while impossible for each and every Canadian, is the best way for experts to communicate progress and uncertainty in the complex science of climate change to specific audiences of leaders, decision makers and the policy community.

Goals

20. The following general goals are suggested for communication of climate system science, impacts and adaptation:
    - to explain the greenhouse effect in plain language and with clear visual images;
    - to make the connection between greenhouse gases, climate change, human behaviour and adaptation;
    - to promote understanding and correct misinformation about the science of climate change;
    - to demonstrate Canadian expertise as an important source of credible scientific information on climate change;
    - to seek third party endorsement of the scientific approach and engage key intermediaries in supportive communications;
    - to communicate information about the potential impacts of climate change on the health of people and their children;
    - to point out that we can develop adaptation options to deal with these impacts; and
    - to explain that there will also be positive aspects to climate change for Canadians.

Communicating the Science

21. For a broad public audience, the challenge in communicating science lies in simplifying both the concepts involved and the language used. In order to meet the objectives described above, short and simple plain-language messages need to be delivered on the following themes:
    - Canadians are uncertain what climate change means and need to know what it is (a long-term natural process that is being affected by people's actions) and what it is not (ozone depletion and El Niño, for example). Surveys have shown that people have very varied and often incorrect ideas

about what climate change is and are confused by climate change and its causes and effects.

- Canadians are being told by some that greenhouse warming is an unproved theory. They need to know that the basic climate system science is not in dispute but that there are uncertainties regarding the extent, timing and regional impacts of climate change. Such uncertainty is precisely the reason for a strong PEO program which identifies the uncertainties clearly, keeps track of the progress science is making, and identifies prudent actions which can be taken now in spite of the uncertainties.

Engaging Canadians in Response Actions

22. People are generally willing to consider changes in behaviour or actions only if they have a clear understanding of why such behaviour changes or actions are required. Pro-active planning and design in advance of the changes is required. Such planning can significantly reduce costs and realize benefits and Canadians will understand that. The following themes are suggested to achieve a PEO program that will encourage Canadians to take response actions in addition and complimentary to mitigation actions which the PEO Table has already identified.
    - Canadians need to know that, particularly in the longer-term, the impacts of climate change around the world will be important to them, not just the impacts that will occur within Canada. They will need to adapt to both.
    - Canadians need to know what adaptation is and what it means for each of them. This definition should include an explanation of the differences between autonomous adaptation and adaptation that occurs as a response to the stimulus of policies and decisions.
    - Canadians need to understand that we cannot continue to adjust in an *ad hoc* and autonomous manner to climate change. Pro-active planning and design are required and can significantly reduce costs and realize benefits.
    - Canadians need to know about the current state of the climate and how it affects them, and need to be shown that it is to their benefit to start adapting now in anticipation of the coming changes rather than waiting until they occur.

23. In order for Canadians to understand what must be done, PEO on adaptation should include messaging that would contribute to enhancing the sustainability of socio-economic systems and ecosystems. This goal can be achieved by describing the impacts of climate change and the need to adapt to those impacts in order to minimize their adverse effects and take advantage of any opportunities they present.

24. Because specific and different adaptive responses to potential impacts will need to be considered by various important social and industrial communities, leaders in such communities should be provided with the information resources to develop their own outreach and leadership programs within their communities.

Recommended Messages

25. The following basic messages supporting public policy development and action on climate change are recommended for consideration in the development of PEO policies and programs by the government.
    - Humans are changing the earth's climate.
    - Emissions reductions made now will moderate the rate of change.
    - Emissions reductions will reduce health-damaging smog, acid rain and mercury contamination.

- Emission reductions, while essential, will come too late to eliminate all climate change and its impacts.
- There's more to climate change than just a little warming. There will be changes everywhere in Canada's weather.
- More severe weather events are likely.
- Climate surprises are a distinct possibility.
- Improving climate change projections through observations and research is a key part of the response.
- Projected changes in climate will have impacts on Canada and on Canadians.
- Changes in the nature of Canada's severe weather and climate surprises may have more significant implications for Canada and Canadians than changes in the average climate.
- Impacts and the capacity to adapt will vary across Canada.
- Climate change may have indirect impacts, notably on human health, and exacerbate problems in activities not normally associated with climate such as provision of health care services.
- Deteriorating availability and quality of water is likely to be an important impact of climate change on Canadians in many regions.
- Adapting now to existing changes will help us minimize the adverse impacts of future changes and help prepare us to take advantage of any opportunities.

Audiences

26. We have identified five categories of audiences for the outreach messages.
    - *Affected and special interest groups* who generally already have a high level of awareness about climate change issues and specific perceptions of what climate change and measures to reduce emissions will mean for them. Of this group, decision-makers in the public and private sector at all levels should be specifically targeted because of the weight their decisions carry. Their informed leadership, in turn, will influence the next category of audience.
    - *The policy community at all levels of government but particularly at the municipal level.* As Canada formulates its long-term policies related to understanding and action on climate change, it is vital to ensure that relevant research results are communicated to that community.
    - *The public* who, generally speaking, are much less aware of climate change issues. Science and adaptation have a critical role to play in outreach to the general public. Before Canadians can be convinced to collectively and individually modify their behaviour to reduce emissions, they need to understand the seriousness of the problem, that it is a real concern and that there will be changes to which they will need to adapt.
    - *Others engaged in outreach and education*, such as the PEO table and groups outside the Table process such as health professionals who are already involved in outreach initiatives. Climate system science and adaptation messages for these groups would be intended to be used by them to augment their messaging on climate change mitigation.
    - *Industry groups, science writers, journalists and broadcast media commentators* who could benefit from clear information on the climate system science and impacts and who can be very influential in promoting immediate action by individuals on adaptation.

27. A more thorough analysis should be undertaken of audiences within each grouping and the most appropriate means of delivering messages effectively to each audience should be determined.

Suggested Delivery Mechanisms

28. The following delivery approaches are suggested for consideration.
    - Briefings and informal discussions with leaders in industry, government and the media by eminent scientists. This approach has been used quite successfully in the U.S.
    - An annual conference aimed at bringing the policy community in touch with active scientists and relevant research results.
    - An ongoing program of educational materials for the development of school curricula.
    - Workshops, information and reference materials aimed at science writers, television reporters and commentators.
    - A press release series on new developments and as response to articles originating here and elsewhere to give Canadian content and flavour.
    - Press releases and media blitz by "unbiased experts" leading up to any significant International event and, as importantly, following the event.
    - Series of monographs dealing with topics on climate system science, each series being aimed at a particular segment of industry or society.
    - Public speaking tours by noted climate system, impacts and adaptation scientists.
    - Articles for the popular press and trade journals on climate system science and adapting to climate change.
    - Trade-show seminars for industries.
    - Media background documents during and after natural disasters.
    - The encouragement of outreach partnerships between the science community and agencies or organizations representing various sectors of society.

29. Because of the importance of the television medium as a delivery vehicle to the general public, consideration should be given to a widely advertised television special or series of specials along the lines of the very successful "The National Driving Test" which was done a few years ago by the insurance industry and carried by a national network. Some of the benefits of such an approach are breadth of audience reach, direct messages from scientists and spin-offs such as videos for use in schools.

Summary

30. The principles, goals, themes, messages and recommendations contained in this chapter will contribute to the understanding and awareness that Canadians will need in order to act in response to the climate change imperative.

31. Canadians' willingness to take action and to commit to the lifestyle changes that will be required in order to reduce greenhouse gas emissions depends on their being convinced of the reality of climate change and its consequences. Canadians also need to be aware that there will be changes in climate to which they will need to know how to adapt in order to preserve their well being, regardless of the extent to which humanity is able to reduce its greenhouse gas emissions. Communicating science well is the key to achieving both of these goals.

32. Moreover, we believe it is particularly important to ensure that, as Canada is considering broad and far reaching policies on mitigation and adaptation, policy makers at the highest levels have an ongoing understanding of the state of the science as it influences that policy.

33. We therefore provide the following two recommendations that are designed to ensure that all Canadians have the ability to make good decisions based on sound science:

Recommendation 1

34. The federal government should design a science-based Public Education and Outreach Program that is specifically designed to meet the principles as outlined at the beginning of this chapter.

35. We offer the following suggestion for such a program at two levels of funding.

Option 1: Basic Program

36. This option attempts to maximize the use of key multipliers or partners in delivering the PEO programs and focuses on providing those multipliers with the information they need.
    - Briefings and informal discussions with leaders in industry, government and the media by eminent scientists. This approach has been used quite successfully in the U.S.
    - An annual conference aimed at bringing the policy community in touch with active scientists and relevant research results.
    - Workshops, information and reference materials aimed at science writers, television reporters and commentators.
    - The encouragement of outreach partnerships between the science community and agencies or organizations representing various sectors of society.

37. Estimated Cost: $300K to $500K annually

Option 2: Full Program

38. This option includes the activities noted above and expands those to include a broader effort aimed directly at the public and at industry. The following mechanisms are added to the list under Option 1.

    - An ongoing program of educational materials for the development of school curricula.
    - A press release series on new developments and as response to articles originating here and elsewhere to give Canadian content and flavour.
    - Press releases and media blitz by "unbiased experts" leading up to any significant International event and, as importantly, following the event.
    - Series of monographs dealing with topics on climate system science, each series being aimed at a particular segment of industry or society.
    - Public speaking tours by noted climate system, impacts and adaptation scientists.
    - Articles for the popular press and trade journals on climate system science and adapting to climate change.
    - Trade-show seminars for industries.
    - Media background documents during and after natural disasters.
    - A television special or series of specials.

39. Estimated Cost: $2M to $3M annually depending on scope and available partners or sponsors. In order to expand television and other materials and develop a stronger program for targeted sectors, funding would need to be increased above this level.

40. We believe it is important for governments to consider sponsoring such a program but that the actual delivery be managed or directed by an independent group or groups at arms length from government. Such a group or groups should be able both to respond to the need for unbiased science expressed in understandable terms, and to form the necessary partnerships and delivery mechanisms.

41. The detailed design of such a program is beyond the scope of this paper, however, as the multi-sector Canadian Climate Program Board, this Table is well situated to assist the government in designing a program and we offer our help in doing so.

Recommendation 2

42. Governments should consider specific actions to ensure that the policy-making community is and remains well-informed on the state of climate system science. To that end we propose the following recommendations for consideration.

43. Efforts should be made to ensure that the policy-making community has direct access to sound science and, in the case of questions for which the answers depend on science which is yet in its infancy, access to the scientists who are actively researching the answers. The most effective way is to put senior public policy makers in personal touch with leading scientists in a continuing series of roundtables or other fora which provide the opportunity for interactive consideration of the main science factors and uncertainties involved in developing public policies around climate change.

44. A regular "State of Climate Science" brief should be prepared for Parliamentarians. A summary of science issues should be prepared with a focus on Canada and timed to complement international IPCC reporting.

45. Consideration should be given to using this advisory table, which has considerable history as the Canadian Climate Program Board, as a continuing authoritative sounding board for any specific policy alternatives being considered.

Recommended Reading

While there are up-to-date references on PEO available from the PEO Table, the following are recommended for background reading to those interested:

Opportunities for Action", A Forum on Climate Change Public Outreach, June 15, 1998, Toronto. Environment Canada, 1998.

Canadians and Climate Change - Analysis of Public Opinion Research, Summary Report prepared for Environment Canada and Natural Resources Canada, Environment Canada. April 1999.

Chapter 7- Conclusions and Recommendations

1. The climate is changing and will change more in the future. We know there will be impacts but we still cannot say exactly what the nature of these impacts will be, when they will become significant and where they will be felt most acutely. Nevertheless, the threat is real. It is an issue that will be with us for generations and will affect all aspects of our society and all parts of our country. We must act now to implement a program that will help reduce the uncertainties so that we can inform and protect our citizens, as well as the ecosystems and economies on which they depend. We need this investment if we are to make the right choices about how to respond to the threat of climate change. This crucial investment is one of climate system science, impacts and adaptation. Climate system science will help us understand what is happening to our climate and how it operates. It will enable us to look into the future, to anticipate the changes to the climate and the impacts that will follow. With the knowledge that comes from reducing these uncertainties we will be better able to guide Canadians and the choices they make regarding the rate and magnitude at which we reduce our emissions and strategies to adapt to the inevitable impacts.

2. This Options Paper, prepared by the Canadian Climate Program Board (CCPB) and its two Advisory Committees, has examined issues related to climate system science, impacts and adaptation as its contribution to the National Implementation Strategy on Climate Change. From the preceding chapters many key points emerge that have been used as the basis for formulating recommendations:

   a. Impacts: the Cause for Concern

   - Impacts and changes in the climate system to date have galvanized government's attention to the issue of climate change.
   - Reducing emissions will slow the rate of climate change and a commitment to the Kyoto Protocol is a good first step.
   - Adaptation is not an alternative response strategy, but rather a complement to emissions reductions; we need to start adaptation now to the impacts that are inevitable.
   - Our response to climate change needs to be based on management of risk.
   - Canada has important international commitments in climate system science, impacts and adaptation.

   b. Science for Emissions Reductions

- Science must contribute to negotiations and implementation of emissions reductions measures in two critical areas.
   - How carbon is sequestered within Canada's ecosystems. We lack the necessary coordination and resources to properly determine the potential of these processes and how they might respond to human interference under a changing climate.
   - The implications of climate change for proposed mitigation measures, as many of these measures are sensitive to a changing climate (e.g., hydro, wind, solar, biomass energy demand). These impacts are poorly known at present.

c. Impacts and Adaptation- Developing an Evolving Strategy

- Adaptation complements mitigation - it is not an alternative.
- We need to begin to adapt now, as there will be impacts even if the Kyoto Protocol emission reduction targets are met.
- The range of impacts must be assessed by sector and by region; the capacity to do this is sorely underfunded.
- Impacts will be felt at the local level and it is here that adaptation options need to be developed and implemented. As such an immediate concentration on municipalities would bring the most immediate and greatest return.
- We know enough about the direction and potential general impacts of climate change to start a targeted research program.
- We need to identify areas in which there are long term implications of adaptation decisions being made now.
- In some cases adaptive response are justified now.

d. Climate System Science- a Necessary Investment

- Climate System Science is an important element of current and future negotiations.
- Augmented systematic observations are needed to:
    - meet our international commitments;
    - understand climate change in the arctic and oceans; and
    - develop new cost-effective techniques and new technologies.
- Regional modeling, including the ocean component are key areas where our skill is lacking and the output critically required by the impacts and adaptation communities.
- Clouds and their radiative feedbacks are among many areas poorly represented in models.
- The university network (CRN) is ideally placed to address gaps in modeling and building scientific capacity.
- There is a need for a facility to develop and provide climate scenarios packaged in a user-friendly format.
- Research on the climate system directed to:
    - understanding the behaviour of sources and sinks is a high priority, particularly for international negotiations; and
    - major areas of uncertainty exist in the roles of sea ice, clouds and aerosols and how they are represented in climate models.

e. Making Informed Decisions

- Canadians' willingness to reduce emissions depends on their being convinced of the reality of climate change and its consequences. Communicating science well is the key to achieving this.
- Canadians need to be aware that there will be changes in climate to which they will need to know how to adapt, regardless of the extent of emissions reductions.
- A PEO program with the following goals is needed to:
    - explain the greenhouse effect;
    - connect greenhouse gases, climate change, human behaviour and adaptation;
    - promote understanding, correct misinformation and respond to critics;
    - demonstrate Canadian expertise as an important source of credible science information; and

- seek third party endorsement of the scientific approach and engage key intermediaries.

- it is also very important to ensure that, as Canada is considering broad and far reaching policies on mitigation and adaptation, policy makers at the highest levels have an ongoing understanding of the state of the science as it influences that policy.

3. Following on the above summary, several key common issues or themes emerge. These themes have been used as the basis for development of the recommendations contained in this chapter. Recommendations have been formulated to:

    - significantly enhance our scientific capacity across the country to understand and predict the climate and to foresee the impacts on Canadians and our socio-economic and environmental systems;

    - prepare Canadians so that their exposure to risks from climate change can be reduced by the development of adaptive options that minimize economic and social costs, sustain their well-being and protect vulnerable ecosystems;

    - provide information to Canadians and decision-makers so that they may make wise choices regarding future greenhouse gas emission reductions and implement suitable adaptation strategies;

    - allow Canadians and their governments to participate knowledgeably, and from a position of scientific credibility, in domestic and international discussions related to the climate change actions, for example on the use of sinks;

    - make a suitable contribution, as a developed country and in our own self-interest, to our knowledge of the climate, its future evolution and possible impacts; and

    - meet our FCCC and Kyoto commitments on systematic observations, climate research and impact studies.

4. A summary of the recommendations is provided below. A more detailed listing, along with an estimate of resources needed for different levels of desired results over the next five years, is contained in the accompanying table. These recommendations have been designed such that they can operate in a synergistic fashion within the realm of climate system science, impacts and adaptation. They are all needed now. The levels of effort and estimated resource requirements in the table have been prepared with this synergistic approach in mind.

5. With respect to **climate system science** the recommendations address the following three key areas:
    - Climate observations
    - Enhance understanding and reduce uncertainties
    - Predicting future climate

    6. Climate observations: *It is recommended that Canada strengthen its observational networks in order to better monitor, detect and attribute changes*

in the climate system. Observations are the basis for understanding and predicting the climate, yet Canadian networks, particularly in the Arctic and our surrounding oceans, are inadequate. Internationally, Canada has made commitments under the FCCC and the Kyoto Protocol to undertake systematic observations of the climate system. The climate observation component should be managed by a new national mechanism such as a *Board for Systematic Observations* in order to ensure maximum benefit. There are two primary elements recommended:

> *A1 - augment systematic observation networks for all five components of the climate system*: atmospheric, oceanic, terrestrial, hydrologic and cryospheric.
>
> *A2 - undertake a research component directed at the development, testing and implementation of innovative approaches to monitoring.* The emphasis should be on exploitation of remote sensing aspects to enhance coverage of the systematic network and to reduce long-term costs.

7. Enhance understanding and reduce uncertainties: *It is recommended that research be undertaken to advance our understanding of the climate system with an emphasis on information that is required to provide a firm scientific basis for Canada's position in international negotiations, particularly regarding greenhouse gas sources and sinks.* There are two primary elements recommended:

> *A3 - implement a program to study greenhouse gas sources and sinks processes*, especially those in our forests, agricultural soils, wetlands, and oceans.
>
> *A4 - undertake a series of field and laboratory studies to reduce the scientific uncertainties* in the operation of key climate processes such as in the Arctic (ocean circulation and sea-ice behavior) and in the forcing of the atmosphere by clouds and aerosols.

8. Predicting future climate : *It is recommended that additional efforts be undertaken to improve projections of future climate, particularly on a regional scale.* The work is urgently needed for impacts and adaptation studies and to inform future international negotiations. There are four key elements recommended:

> *A5 - strengthen our ocean modeling capacity.* There is a need to build a stronger capacity for ocean model development in Canada. Gaps in regional and basin scale ocean models need to be addressed, and techniques developed for the assimilation of this data into models.
>
> *A6 - strengthen the Climate Research Network.* This government/university initiative should be expanded into areas where the largest scientific uncertainties exist, such as the carbon cycle, clouds and radiation and extreme climate events. This would also

accelerate building of Canadian scientific capacity, particularly in universities.

A7 - enhance the national climate modeling capacity. This would enhance Canada's climate modeling expertise in the Canadian Centre for Climate modelling and analysis (CCCma) , strengthening our skill at making predictions at regional scales, and ensuring supercomputer capacity is available to run these increasingly complex models.

A8 - establish a facility for the provision of climate scenarios. There is a need to establish an ability to provide packaged climate model outputs (scenarios) to researchers involved in impacts and adaptation studies. The capacity would be a collaborative enterprise between the universities and the federal government.

9. As mentioned earlier, the climate system science recommendations have been designed such that they can operate in a synergistic fashion, and feed needed information to the impacts and adaptation researchers as well as the policy community. For example climate models, and study of climate processes, depend on availability of climate observations. In turn, results from climate process studies can help better delineate at what spacing and frequency climate observations should be made. Climate scenarios are only as credible for regional impact studies as the regional climate models that they are based upon. Similarity, monitoring the concentrations of greenhouse gases in the atmosphere and understanding the processes involved in key sources and sinks is essential if we are the build carbon-cycle models that will be able to translate future emissions into atmospheric concentrations.

10. In concert with the above issues, the CCPB believes that recommendations in **impacts and adaptation** issues should be addressed within four complementary components:
    - Research program
    - Program delivery
    - Capacity building
    - Adaptation governance

    B1 - Research program*:* Impacts and adaptation research are relatively new areas. *It is recommended that an impacts and adaptation research program be implemented to*:
        - document the sensitivities and vulnerabilities of ecosystems and regional communities to current and past climatic changes, and estimate likely future impacts and assess their implications for ecosystems, socio-economic and other human systems;
        - estimate the adaptations which are likely to occur "autonomously" under climate change in ecological and socio-economic (human) systems;
        - identify and develop specific adaptation options which could be undertaken to reduce vulnerabilities associated with climate change in the various sectors, regions and communities; and assess their potential effectiveness, benefits and costs, implementation, etc.; and

- develop recommendations concerning adaptation measures for selected key regions and sectors that should be implemented immediately; and
- develop and employ an integrated assessment capability, and collaborate internationally in this effort.

B2 - Program delivery: Impacts and adaptation research efforts in Canada are not well coordinated. To provide coordination of research activity, climate impact assessments, and a mechanism for stakeholder involvement, *a Canadian Climate Impacts and Adaptation Research Network (C-CIARN) should be established with regional and sectoral composition.*

B3 - Capacity building. To ensure that the Canadian research capacity in governments, universities and industry can deal with the range of issues that must be addressed, *a significant investment in analytical capacity and a targeted research program should be made now, to enhance scientific capacity in impacts and adaptation. Such an investment would stimulate:*

- scientific capacity in federal departments
- capacity building in universities
- training and development through granting councils

B4 - Adaptation governance: *An appropriate governance structure should be established for dealing with impacts and adaptation research results.* Implementation of adaptation measures will involve governments at all levels as well as the private sector and individuals. At the national level there will be a need to address *inter alia* implementation costs and barriers and conflict resolution. A formal process needs to be set up, similar to that for mitigation, to guide the analysis of adaptation options.

11. *The CCPB recommends that Canadian climate change scientists be engaged to participate in a major climate change* **communications** *initiative*. Independent studies confirm that there is no community more qualified or respected to communicate the facts and consequences of climate change than the climate system science, impacts and adaptation research community. In addition, the governments have a responsibility to ensure that all sectors of the policy-making community have access to sound science and to scientists who are actively researching the answers. A communications program encompassing these concerns would be characterized by the following thrusts:
    - Public education and outreach
    - Dialogue with decision-makers

    C1 - Public education and outreach. *It is recommended that an initiative be created to improve the Canadian public's understanding of climate change, the need to reduce greenhouse gas emissions and take measures to adapt to climate change.*

    C2 - Dialogue with decision-makers. The objective of this initiative would be *to initiate a dialogue with industry and all levels of government to ensure that state-of-the-art climate system science, impacts and adaptation information is available for decision-making.* Consideration should be given to supporting the Canadian Climate Program Board to implement this initiative.

Detail of Recommendations by Level of Effort[10]

Recommendation			Level of Effort		
			Low	Medium	High
Climate System Science - *Monitoring*	A1	*Systematic Observation Network* Estimated investment: $21-28M	-fill at least 50% of gaps in atmospheric network in north -oceans: modest program of sub-surface observations, vertical cross - sections, sea-level stations in Atlantic & Pacific oceans -deployment of at least 50% of sub-surface profiling floats needed as CDN contribution to international ocean monitoring -other monitoring components - installation of 1 or 2 sites in each of following networks, all of which are contributions to international climate networks: carbon-flux, permafrost, glacier mass-balance, atmospheric composition	- atmospheric network approaching international standards - oceans: "low" + better Arctic coverage; the remainder of Pacific floats; continental shelves; Arctic Archipelago outflow -other monitoring components - 4 carbon flux stations; viable permafrost network; 3 atmospheric composition sites; glacier mass balance measurements in Arctic & cordillera regions - coordinated management & dissemination of collected information	-adequately fill gaps in all 5 monitoring components
	A2	*Innovative Monitoring Approaches* Estimated investment: $3-4M	- limited infusion of new techniques into observation systems - permit some development of partnerships	- establish Canadian base of expertise in partnership with universities and Canadian Space Agency - allow international collaboration on projects of interest to Canada	- fast tracking of the implementation of innovative approaches in Canada

10 low - a minimum level below which progress to address needs could not be achieved
medium - a level at which significant progress on addressing some needs would be achieved
high - a level at which most of the identified needs would be addressed

		Canadian Board for Systematic Climate Observations Estimated investment: $100 -300K			
Climate System Science - *Enhance Understanding & Reduce Uncertainties*	A3	*Carbon Sources & Sinks Processes* Estimated Investment: $11-16M	- quantification of greenhouse gas sources and sinks in selected natural and managed systems (mainly forests and agricultural land) - some support would be provided to university partners	- comprehensive understanding of Canadian sources and sinks, including wetland and peatlands; -additional university and some international collaboration would be possible	- fast tracking of the quantification of sinks and sources for all terrestrial, marine and oceanic systems - incorporation of results into models, - permit strong contribution to university research - ensure full partnership with BIOCAP and other domestic and international initiatives
	A4	*Climate Processes- Field & Laboratory Studies* Estimated investment: $5-8M	-enhancement of ongoing studies linked to international climate programs (topics such as: land-atmosphere energy exchange; paleoclimate reconstruction; and ocean dynamics)	- meaningful level of participation, with emphasis on the Canadian north and the Arctic, northern oceans, the cryosphere and the water cycle	- a significantly enhanced level of effort in all areas of atmospheric research, with a consequent speed-up of program delivery - for the paleoclimate area, complementary computer modeling would be added to the projects, which are primarily university based - in the oceans, major studies would be undertaken in the Arctic and the open ocean (with international partners)

Climate System Science - *Predicting Future Climate*	A5	*Ocean Modeling* Estimated investment: $1.5-2M	- address gaps in regional and basin-scale ocean models - develop techniques for assimilation of data into ocean models	- provide the capability to meld ocean models and new ocean data - improve how physical processes are represented in ocean models	- ensure that routine multiple ocean computer runs are undertaken to assess potential model improvements and improve climate scenarios
	A6	*Climate Research Network* Estimated investment: $2-3M	- establish a new CRN node on clouds and radiation - augment the existing carbon cycle node	- add nodes on extreme climate events, cryosphere modeling, and the water cycle	- permit easier access by CRN researchers to climate model results - add some node-specific computing support - facilitate implementation of new modules into the global climate model
	A7	*National Climate Modeling* Estimated investment: $3-5M	- acquire experienced ocean circulation modeler & support for regional & global climate model - provide some supercomputer capacity.	- modeling capacity for carbon and sulfur cycles - ensure that modest supercomputing capacity is available	- add modeling capacity for atmospheric chemistry - ensure that adequate supercomputing capacity is available
	A8	*Climate Change Scenarios* Estimated investment: $2-3M	- provide a basic capacity, able to interact with and service impacts and adaptation research communities on a limited basis	- fund a viable capacity - permit modest engagement of the university communities to interact with users - make productive linkages with similar groups in the UK and US	- permit the establishment of a significant core of expertise which could be expected to produce scenarios on request for the various user communities - substantial university involvement would be assured

Impacts & Adaptation	B1	*Impacts & Adaptation Research* Estimated investment: $15-54M	- staged program introduced - representative Municipalities from across Canada studied - sectoral issues, in some priority (Chapter 4) will be covered - additional sectors will be covered but through a municipal perspective - National assessment completed	- all policy sectors (Chapter 4) including Municipalities, Water Resources, Food Supply, Human Health, Forests, Landscapes and Ecosystems; and Coastal Zones to be covered in some detail in all areas of the country - a major focus remains on Municipalities - National assessment completed	- all sectors discussed in Chapter 4 of the Options Paper will be considered for all regions of the country - emphasis on priority sectors - National assessment completed
	B2	*C-CIARN* Estimated investment: $1-8M	-at the lowest level of funding CCIARN will form a simple network with funding facilitating national and regional meetings, support a secretariat - co-ordination will be provided and a coherent program (above) commenced	-funding will provide support to a PI and assistant in each of 6 regional nodes and 10 sectoral nodes, as well as fund some activities and regional, national meetings - additional support will also ensure better long-term development of the program (i.e. beyond single-issue interests)	-additional funding will support the creation of several dedicated regional research centres and provide needed impetus to regions requiring it
	B3	*Building Research Capacity* Estimated investment: $4-10M	-five year funding to be used in universities and federal laboratories, on a 1:1 hiring basis. - recommended that for each position created funding be available to offset the cost of filling a second position	- size of program relative to the lower level will be enhanced	funding allocated to granting councils to fund studentships and post-doctoral fellowships in impacts and adaptation research, tenable at not only universities and government institutions but also at industrial laboratories whose work is freely published

	B4	*Governance Structure* Estimated investment: $1-3M	-scoping studies completed, recommendations developed, funds to support minimal governance structure	- structure enhanced	- structure equivalent in scope to that created for managing mitigation to be put in place by end of funding period
Making Informed Decisions	C1	*Public Education and Outreach* $500K-3M	briefings & informal discussions with industry leaders, government, & the media by eminent scientists. - annual conference aimed at bringing the policy community in touch with relevant research results - workshops, information & reference materials aimed at science writers, TV reporters & commentators - encourage outreach partnerships between the science community & agencies/organizations representing various sectors of society		- ongoing program of educational materials for the development of school curricula - press release series on new developments & as response to articles to give Canadian content/flavour - press releases & media blitz by "unbiased experts" prior to and following any significant international event - monograph series - public speaking tours by climate system scientists - articles for the popular press, trade journals - trade show seminars for industries - TV special or series of specials - media "backgrounders"

	C2	*Dialogue with Decision-makers* - (no cost projection)			- creating of a "State of Climate Systems Science" report for parliamentarians - initiate science roundtables with senior policy makers - use of the CCPB as an advisory body for climate system science, impacts and adaptation